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STUDIES ON APPLE ROOTSTOCK SELECTIONS RELATING RESPIRATION RATES TO AN ANATOMICAL METHOD OF PREDICTING DWARFNESS[1]

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[Received for publication June 16, 1960]

ABSTRACT

The respiration rates of leaf disks and root tips of apple rootstock selections are related to the per cent of bark in the root which has been shown to be an index of dwarfing potential. In 1958 and 1959 significant regression coefficients were shown between the respiration rate of leaf disks and the per cent of bark in the roots. A highly significant regression coefficient was obtained between the respiration rate of the root tips from rooted softwood cuttings and the known per cent of bark in the root of the parent plant. The data indicate that the respiration rate of leaf disks or root tips would be a satisfactory measure of dwarfing potential within a closely related series of apple rootstock selections.

INTRODUCTION

In recent years there has been an increased interest in dwarf and semi-dwarf apple rootstocks for commercial apple production. Since Malling IX, the best known dwarfing rootstock, lacks sufficient hardiness for most of the apple-producing areas in Canada, the selection of hardy rootstocks which will induce dwarfing into the scion variety has become very important.

Although the final decision on tree vigour must be based on field trials, the large acreages and the amount of labour and time required limit such tests to a few selections. Beakbane and co-workers (1) have devised a method of evaluating dwarfing rootstocks based on the per cent of bark which is present in the cross-sectional area of adventitious roots of apple. Such histological procedures are laborious and time-consuming and more rapid methods would be desirable.

This paper discusses the results of experiments conducted in 1958 and 1959 to correlate micromanometric measurements of the rate of oxygen absorption of leaf disks and root tips of apple selections with the per cent bark in the cross section of the root.

MATERIALS AND METHODS

Clonal selections from seedling populations of *Malus* sp. are at present growing in stoolbeds at Ottawa. These selections have been rated as to the vigour they should produce in a scion variety using the per cent of bark on 7-8 mm. adventitious roots as a criterion (1).

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Leaf Material

The third fully developed leaf from the apex of the plant was collected from each of 10 plants and taken immediately to the laboratory. One leaf disk, 8 mm. in diameter, was removed from between the veins of each leaf with a cork borer. Eight such disks were taken at random and placed in the bottom of a Warburg flask with 0.2 ml. of water.

A buffer solution, containing diethanolamine, hydrochloric acid, potassium bicarbonate and water, maintained a constant 1 per cent carbon dioxide atmosphere within the vessel (3). The vessels were placed in a constant temperature water bath at 37°C. in complete darkness. After an equilibrium period of 10 minutes, the system was closed and respiration determinations (O_2 uptake) were carried out for a total of 2 hours. To ensure uniformity, readings were taken at 15-minute intervals although the final data were based on hourly readings. Dry weights of material used (8 disks) were determined after drying the material for 24 hours at 105°C. Respiration was calculated as microlitres of oxygen absorbed per milligram of dry material per hour.

Determinations were made on 18 selections in 1958 and 19 selections in 1959 with tissue of *Malus robusta* 5 common to all series. The rate of oxygen absorption was determined four times between mid-July and mid-September and for purposes of statistical analysis the data from the four determinations were considered to be replicates.

Leaf material from *Malus robusta* 5, a vigorous rootstock, was present in each series and in order to remove the variability which existed between the rate of oxygen absorption between mid-July and mid-September, the amount of oxygen absorbed by each seedling was expressed as percentage of that absorbed by *Malus robusta* 5 at each date.

Root Material

In 1959, softwood cuttings were taken from 10 of the *Malus baccata* selections and rooted outdoors during the summer in a polyethylene tent with intermittent mist. After the cuttings had rooted, 15 root tips, each approximately 1 centimetre long, were removed and placed in the Warburg flask. Three separate determinations of the respiration rate were made on each selection.

RESULTS AND DISCUSSIONS

Leaf Material

The data, summarizing the 1958 results, are presented in Table I. Of the 18 selections used, 7 had a significantly lower rate of oxygen absorption than the vigorous *Malus robusta* 5. Of these 7, at least 5 would be considered either dwarfing or semi-dwarfing on the basis of the per cent bark index. One selection, *Malus baccata* 23, with 51.2 per cent bark, would be considered borderline. The remaining selection, *Malus baccata* 11, with 48.1 per cent bark, would be classified as being vigorous using the amount of bark as an index even though the respiration rate was significantly lower than the vigorous *Malus robusta* 5.

TABLE I.—PER CENT OF BARK IN THE ROOT AND RESPIRATION RATE OF LEAF DISKS COLLECTED FROM APPLE SELECTIONS DURING THE 1958 AND 1959 SEASON

Seedling	Per cent root bark	Respiration rate[1]	
		1958	1959
Malus baccata 1	49.7	97.8[2]	98.4[2]
Malus baccata 3	47.5	96.5	84.5
Malus baccata 4	55.6	86.4	76.1
Malus baccata 5	51.4	–	79.0
Malus baccata 6	51.2	92.9	66.4
Malus baccata 7	49.7	–	87.3
Malus baccata 8	51.4	106.6	98.6
Malus baccata 9	56.8	84.1	–
Malus baccata 11	48.1	82.8	97.3
Malus baccata 12	47.3	97.5	97.5
Malus baccata 17	46.8	90.3	79.9
Malus baccata 18	41.1	95.2	93.9
Malus baccata 23	51.2	88.2	93.8
Malus baccata 25	60.4	85.9	70.3
Malus baccata 27	61.6	77.0	75.2
Malus baccata 28	49.9	95.3	94.4
Malus baccata 34	44.7	–	93.1
Malus baccata 48	46.0	–	81.5
Malus baccata 51	52.2	–	95.7
Malus baccata siberica 3	42.5	101.1	–
Antonovka	61.1	83.0	–
Malus robusta 11	60.7	93.5	–
Malus robusta 5	—	100.0	100.0
5% LSD	—	11.8	14.1
1% LSD	—	15.7	18.7

[1]Respiration rate expressed as a percentage of *Malus robusta* 5
[2]Each value is the mean of four determinations

The regression line relating the per cent bark in the root to the per cent respiration of leaf disks for 1958 is presented in Figure 1. A highly significant regression coefficient of – 0.7133 was obtained. When all 18 selections are compared, using the regression line obtained in 1958, only 3 deviate considerably from the expected values. Of these, *Malus baccata* 11 had a lower rate, whereas *Malus baccata* 8 and *Malus robusta* 11 had higher respiration rates than indicated by the per cent bark index. This latter selection had a rate of oxygen absorption for one replicate which was 18 per cent higher than the average of the other three which could partly explain the difference. It is also possible that this selection, being of a different species, could have a higher respiration rate than the *Malus baccata* selections.

Although it was felt that more consistent results would be obtained by analysing a closely related series of *Malus baccata* selections, the 1959 data, summarized in Table I, were more variable than those obtained in 1958. This greater variability may be explained in part by the drought conditions which occurred during July and August. As a result the apparent respiration rate may not have been compensated for by expressing the results as a percentage of *Malus robusta* 5. There was, however, a significant regression coefficient (—1.0533) in 1959 between per cent respiration of the leaf disks and per cent bark in the root.

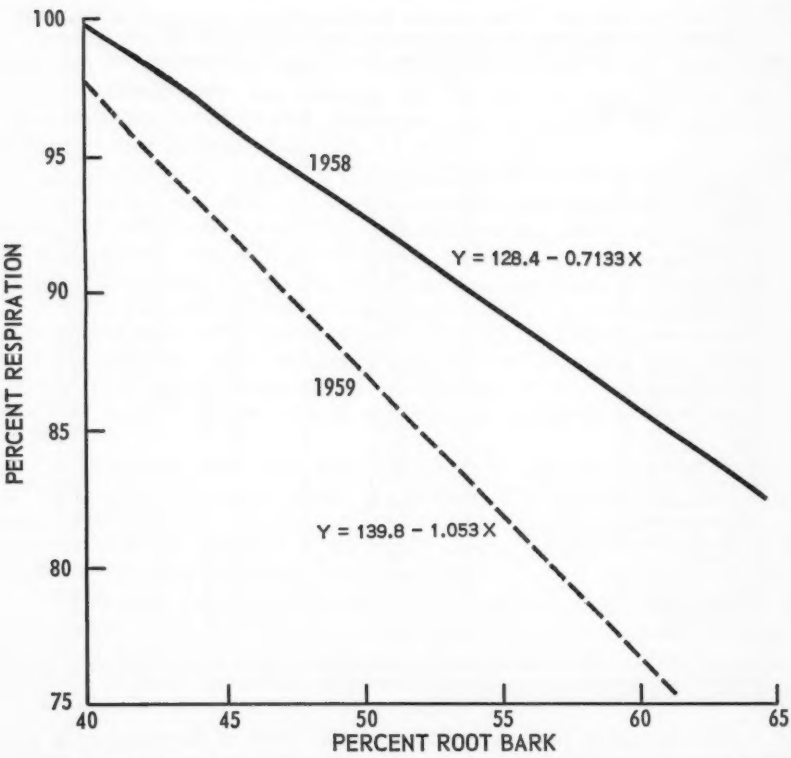

FIGURE 1. The regression of respiration of leaf disks expressed as per cent of *Malus robusta* 5 on the known per cent bark in the adventitious roots of a series of clonal rootstock selections.

Of the 18 selections studied in 1959, 8 had a significantly lower rate of oxygen absorption than the vigorous *Malus robusta* 5. Of these 8, 5 had over 50 per cent bark in the roots, indicating a dwarfing tendency. The remaining 3 selections, *Malus baccata* 3, 17, and 48, would be considered vigorous on the basis of the amount of bark present. Two of these, *Malus baccata* 3 and 17, were included in the 1958 trial but did not show a significantly lower respiration rate. Three of the selections with slightly over 50 per cent bark in the roots did not have a significantly lower respiration rate in 1959.

In summary, the use of respiration rates of leaf disks as an index of the dwarfing potential of a closely related series of apple rootstocks was reasonably satisfactory. In 1958, of the 9 selections with over 50 per cent bark, 6 would have been selected as having dwarfing potential on the basis of respiration rate. Two of the remainder were borderline for bark percentage and the other was *Malus robusta* 11, a different species. In 1959, of the

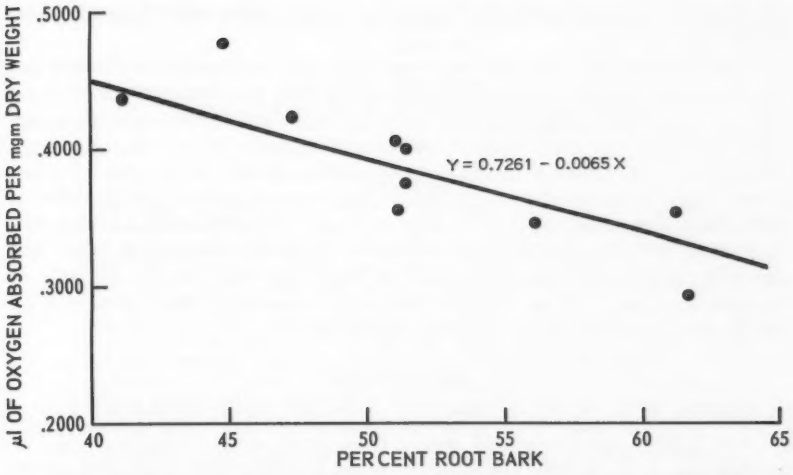

FIGURE 2. The regression of respiration of root tips expressed as μl. of 0_2 absorbed per mgm. of dry matter per hour on the known per cent of bark in adventitious roots of a series of clonal rootstock selections.

8 selections with greater than 50 per cent bark, 5 had significantly lower respiration rates than *Malus robusta* 5 and the remaining 3 were borderline for bark percentage. Admittedly, 1 selection in 1958, and 2 selections in 1959 with low respiration rates, would have been selected as dwarfing in spite of the relatively low per cent of bark in the roots.

Root Material

Since there appeared to be a greater degree of variability than desired in the leaf data, attempts were made to increase precision by using root tips. Hassan, as reported by Beakbane (2) has shown that the respiration rate of root portions was higher in vigorous than in dwarfing apple rootstocks.

The measurements of the respiration rates of the root tips of the apple selections are summarized in Figure 2. A highly significant regression coefficient of —0.0065 (P less than .01) was found between the amount of oxygen absorbed by the root tips and the per cent of bark in the root.

Even though the regression coefficient indicated that an excellent relationship exists, no significant differences between the respiration rates of the various selections was found which undoubtedly was due to the small number of measurements which were made, as well as the small differences in the respiration rate which existed between selections. In subsequent trials, more and larger samples of root material will be used in an attempt to establish significant differences.

On the basis of the 1959 results with the root material, it is possible that this material may be a more reliable index of the dwarfing potential of apple selections than leaf disks. Although the necessity of rooting the cuttings may be a disadvantage it is felt that the greater control of the moisture

conditions, rooting media and nutrition under mist outweighs this disadvantage.

The limited use that has been made of this manometric technique has demonstrated that, in order to obtain results that are similar to those using the per cent bark, selections must be used which are closely related; otherwise discrepancies may occur. In view of this, it is felt that the most satisfactory procedure is to restrict the studies initially to a series of selections arising from specific controlled crosses between parents which differ in their dwarfing ability. In this way a range of values will be obtained, indicating either a dwarfing or vigorous tendency depending upon the apparent respiration rate. Selection of seedlings with the lowest rate of oxygen absorption offers a rapid method of separating the vigorous from the dwarfing rootstocks in a closely related series.

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CONTROL OF POWDERY MILDEW ON TUBEROUS BEGONIA IN CANADA[1]

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[Received for publication August 16, 1960]

ABSTRACT

Powdery mildew is recognized as the most important disease affecting tuberous begonias in Canada. Six fungicidal preparations were tested for the control and eradication of the disease on infected plants at Ottawa in 1955, 1956, and 1957. A spreader-sticker, Orvus, was added to each spray at the rate of 5.5 ounces per gallon. Karathane WD, at 6 or 8 ounces per 80 imperial gallons of water, applied three times at 3-day or weekly intervals, controlled and completely eradicated the disease in all tests. A bleaching of the petal edges was the only injury caused by the spray. Two per cent Karathane dust also controlled and eradicated the mildew. Three applications of Captan 50W, Fermate plus sulphur, and Omazene, prevented spread of the disease but did not give satisfactory eradication of the mildew. Actidione at 1 p.p.m. and 2 p.p.m. controlled and eradicated the disease in 1956. In 1957, the disease was reduced by the first two applications of Actidione but before the third was applied, the plants were accidentally injured by other factors and final results were not obtained.

INTRODUCTION

Powdery mildew on *Begonia* was first reported in Canada in 1948 when it was identified on leaves of tuberous begonia and elephant's ear begonia by Vanterpool and Savile (6)[3]. The disease was not reported again on tuberous begonias until 1951 (7). Subsequent reports from various localities (1, 2, 4, 8, 9, 10) indicate increased concern about the disease and establish it as the most important one of tuberous begonias. Powdery mildew is attributed to the fungus *Erysiphe cichoracearum* DC although the perfect stage of the fungus has not been found on infected tuberous begonias.

Captan sprays controlled powdery mildew on tuberous begonias in the United States (3, 5). As this did not give satisfactory control when used on commercially grown plants at Huntsville, Ontario, in 1955, experiments were started at Ottawa to test a number of fungicides for the control and eradication of the mildew on infected plants. Also, sulphur dust was tested for protecting healthy plants against infection. The results of experiments done during 3 years are reported here, and recommendations are given for controlling and eradicating the disease.

MATERIALS AND METHODS

The plants for the fungicide tests were grown in the greenhouse where they developed variable natural infections of mildew. Plants that developed moderate to severe infection early in the season were used in outdoor tests. Those that did not develop sufficient mildew until late summer were used for tests in the greenhouse.

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[2]Plant Pathologist.
[3]All reports that have appeared in the *Canadian Plant Disease Survey* were checked with the original slips submitted by the reporter to ascertain that the host was *Begonia tuberhybrida* Voss.

The fungicidal preparations used, their concentration and schedule of application were as follows:

Actidione [3-(2(3,5-dimethyl-2-oxocyclohexyl)-2-hydroxyethyl)-glutarimide], 1 p.p.m. and 2 p.p.m., each concentration applied at 7-day intervals.

Captan 50W (50 per cent captan), 25.5 ounces per 80 imperial gallons applied at 3-day and 7-day intervals.

Fermate (76 per cent ferric dimethyl dithiocarbamate) plus sulphur, 16 ounces of each per 80 imperial gallons applied at 7-day intervals.

Karathane—2 per cent dust. The plants were redusted after rains and to cover new growth.

Karathane WD (22.5 per cent dinitro capryl phenyl crotonate plus 2.5 per cent other nitro phenols and derivatives, chiefly dinitro capryl phenol), 6 ounces and 8 ounces per 80 imperial gallons, each concentration applied at 3-day and 7-day intervals.

Omazene (50 per cent copper dihydrazinium sulphate), 12 ounces per 80 imperial gallons applied at 3-day and 7-day intervals.

Sulphur-dust. The plants were redusted after rains and to cover new growth.

A spreader-sticker, Orvus, was added to each of the sprays at the rate of 5.5 ounces per 80 imperial gallons. Sulphur was dusted on 10 healthy plants to determine its effectiveness in protecting the plants against infection. Many growers have found that sulphur dust does not always give complete protection from mildew and it is necessary to apply an eradicant fungicide such as Karathane. To determine whether or not the two fungicides are compatible, sulphur-dusted plants were sprayed with Karathane WD.

The fungicides were applied when the temperature did not exceed 85°F., and the plants were shaded to prevent possible sun-scorching of the wet foliage. The sprays were applied to both sides of the leaves as well as the stems.

The fungicides were evaluated by their effectiveness in controlling the disease, as indicated by the elimination of spread of the mildew to previously uninfected leaves, and in eradicating established lesions. Microscopic examinations were made of mildew spots to determine if the fungus was alive. It was found in early tests that three applications of Karathane WD gave good control of the mildew. Therefore, three applications were used for all subsequent tests with fungicides.

RESULTS AND DISCUSSION

The results obtained with six fungicidal preparations in tests to control and eradicate the disease on infected plants in 1955, 1956, and 1957 are given in Table 1.

Each year the check plants became progressively more heavily infected with mildew as the summer advanced, many of them finally being killed.

In all tests, the disease was controlled and completely eradicated by three applications of Karathane WD used at 6 or 8 ounces per 80 imperial gallons of water and applied at either 3-day or weekly intervals. Two per cent Karathane dust also controlled and eradicated the mildew. In these tests, when the disease was eradicated by the three applications of the spray no additional sprays were made unless the plants became re-infected by air-borne spores from the check plants or from infected plants in the vicinity. The time for the plants to become re-infected after the original

TABLE 1. — THE EFFECTS OF FUNGICIDES IN TESTS FOR THE CONTROL AND ERADICATION OF POWDERY MILDEW ON TUBEROUS BEGONIAS

Fungicide	Concentration	Interval between applications[1]	Location of plants[2]	No. of plants with mildew controlled and eradicated / No. of plants treated			Injury to flowers[3]	Visible deposit[3]
				1955	1956	1957		
Karathane WD	8 oz./80 imp. gal.	3 days	O	99/99	10/10	10/10	S	S
		7 days	O	87/87	10/10	10/10	S	S
	6 oz./80 imp. gal.	3 days	O		10/10	10/10	S	S
		7 days	O		10/10	10/10	S	S
Karathane	2% dust	As required	O		10/10	10/10	N	M
			G		10/10		N	M
Captan 50W	25.5 oz./80 imp. gal.	3 days	O	100/132			N	M
		7 days	G			5/10	N	M
Fermate plus sulphur	16 oz. of each/ 80 imp. gal.	7 days	O		6/8	8/10	N	H
Omazene	12 oz./80 imp. gal.	3 days	G		4/10		M	S
		7 days	G		4/10		M	S
		7 days	G			1/10	N	S
Actidione	1 p.p.m.	7 days	G		4/4	—/10	N	N
	2 p.p.m.	7 days	G		4/4	—/10	N	N
Untreated check				0/67	0/10	0/10		

[1]Three applications of the sprays were made
[2]O - outdoors; G - greenhouse
[3]S - slight; M - moderate; H - heavy ; N - none

infection was eradicated varied from 2 to 4 weeks, depending on the prevalence of mildew in the neighbourhood and the environmental conditions. The only injury caused by Karathane WD was a bleaching of the petal edges. The white residue left on the leaves by the spray, unlike the yellow Karathane dust, was only slightly evident and did not detract materially from the appearance of the plants. The mildew spots on the sprayed plants often turned yellow because of the accumulation of the fungicide deposit in the mycelium. These sometimes disappeared completely, but more often remained as grey or brown necrotic spots.

Three applications of Captan 50W applied at either 3-day or weekly intervals prevented spread of the mildew but eradicated it on only some of the plants treated. In 1955, mildew on plants still infected after being sprayed with captan was eradicated by Karathane WD applied three times at 3-day intervals. In 1957, six applications of captan were required to eradicate the disease on all of the 10 plants treated. Captan caused no phytotoxicity. The large number of applications required and the unsightly greyish deposit of fungicide left on the leaves makes Captan 50W an unsatisfactory fungicide for eradicating the mildew.

A spray consisting of Fermate and wettable sulphur reduced the severity of the disease but did not give complete eradication of the mildew. The spray was not phytotoxic but the black deposit left on the leaves made the plants very unsightly.

Omazene checked the spread of the disease but eradicated it on only 4 of the 10 plants treated in 1956 and on only 1 plant in 1957. The severity of the disease on the remaining plants was appreciably reduced. Six applications of the spray did not eradicate the disease but reduced it to light proportions. The fungicide caused a necrosis of the petal edges in 1956 but not in 1957. The white deposit left by the spray was conspicuous where it accumulated in leaf depressions.

Actidione used at 1 p.p.m. and 2 p.p.m. controlled and completely eradicated the mildew on the treated plants in 1956. It was not phytotoxic and it left no visible deposit on the leaves. In 1957, the first two applications of Actidione reduced the disease but, before the third application, the plants were accidentally damaged by other factors and final results were not obtained.

Dusting healthy plants with sulphur protected them against infection but the film of dust on the leaves detracted from their appearance. Sulphur-dusted plants sprayed with Karathane WD showed no injury other than the bleaching of the petal edges which also occurs when the latter fungicide is used alone.

Karathane, used either as a spray or dust, controlled the disease and it was the most effective of the fungicides tested for the eradication of powdery mildew on tuberous begonias. Under conditions particularly favourable for the development of mildew it is recommended that the fungicide be applied to the plants at 3-day intervals. Under conditions less favourable for the disease, weekly applications should give satisfactory control. Spraying should be done as soon as the disease is noticed on the plants.

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THE INFLUENCE OF A COMMERCIAL FERTILIZER TREATMENT ON WEED COMPETITION IN SPRING SOWN WHEAT[1]

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ABSTRACT

Applications of ammonium phosphate fertilizer (11-48-0) at 40 pounds per acre on six farm fields in Manitoba were effective in reducing losses in wheat yields caused by weed competition. Average losses in yield due to weed competition were 20.5 per cent in unfertilized portions of the fields and only 11.7 per cent in fertilized portions of the same fields. Increases in wheat yields resulting from fertilizer treatment were approximately equal to increases resulting from weed removal. However, higher yields resulting from fertilizer treatment were sometimes accompanied by decreases in the protein content of the harvested crop. Increased yields resulting from weed removal were generally accompanied by significant increases in the protein content. The combined effects of fertilizer treatment and of weed removal produced the largest increases in yield of wheat and maintained the protein content at a comparatively high level.

INTRODUCTION

Weeds compete with cereal crops for moisture, plant nutrients and possibly light. Since these three basic requirements are seldom available in proportions adequate for maximum crop production, yields of cereal crops can only be maintained at a maximum where weed competition is limited. Controlled competition studies in wheat and flax initiated at the University of Manitoba in 1952 demonstrated that as few as 10 wild mustard plants per square yard in flax, or 50 wild mustard plants in wheat caused significant reductions in yield (2, 3). Weed competition was found to commence early in the growing season and, therefore, the need for weed removal at an early stage of crop growth was very evident (13). Experiments on Manitoba farm fields revealed that all crops studied suffered substantial losses in yield from weed competition (4). Decreases in protein content of wheat and barley were also noted (5).

The above-mentioned series of weed competition studies were conducted at one level of soil fertility. Other investigators have demonstrated that application of mineral fertilizers with grain and other crops effectively reduced losses from weed competition (1, 6, 7, 11, 12). The effects of fertilizer treatment were commonly manifested by reduced weed seed populations in the soil (7, 11), more rapid growth of crop seedlings (6, 7), earlier crop maturity (7), increased tillering in cereals (12), increased yields (1, 7, 8), improved quality of crops (1), and reduced incidence of diseases such as Browning root rot (14). Nevertheless, little is known of the importance of commercial fertilizers in reducing weed competition under actual farm conditions. The project described in this paper was undertaken to evaluate the significance of a commercial fertilizer as a means of combating weed competition on farm fields.

[1]This material is taken from the senior author's thesis presented to the Faculty of Graduate Studies and Research of the University of Manitoba in 1959 in partial fulfilment of the requirements for the degree of Master of Science.

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MATERIALS AND METHODS

The project was conducted in 1958 on "fertilizer trial strips" laid out on six farm fields in Manitoba by the Department of Soil Science, University of Manitoba. The soil types for each of the six fields are as follows:

Location number	Soil description
1	Dark Grey Wooded, Erickson Association, well drained clay loam.
2	Dark Grey Wooded, Erickson Association, well drained clay loam.
3	Grey Wooded, Waitville Association, well drained loam.
4	Dark Grey Wooded, Rose Ridge Association, well drained clay loam.
5	Black, Portage Association, moderately well drained clay loam.
6	Black, Portage Association, moderately well drained clay loam.

All fields had been summerfallowed the previous summer and were sown to Selkirk wheat in 1958.

Fertilized strips and check strips in these fertilizer trials consisted of 12 or 14 6-inch drill rows (one-half the width of farmer's drill) and were one-half mile in length. The fertilized treatment included a 40-pound-per-acre application of monoammonium phosphate (11-48-0) drilled in with the seed. Shortly after the wheat emerged and the boundaries of the treated strips became discernible, a row of ten paired plots, each 4 feet by 4 feet, was staked in each of the fertilized strips and adjacent check strips. Paired plots were spaced 60 paces apart in each strip. One plot of each pair was maintained weed-free by hand weeding and the other was left in its natural weedy condition. "Weeding" of the plots commenced soon after the weeds emerged and was repeated thereafter at intervals of approximately 10 days. Weed seedlings removed from the plots were placed in polyethylene bags and brought to the laboratory for counting and identification. Square-yard samples were harvested from the centre of each plot when the wheat reached maturity. Protein content of the grain was determined by the standard Kjeldahl procedure. Moisture in the samples was determined by drying at 130°C. and protein results calculated to a 13.5 per cent moisture level.

TABLE 1. — AVERAGE NUMBER OF WEEDS PER SQUARE YARD UNDER TWO LEVELS OF SOIL FERTILITY ON SIX FARM FIELDS, 1958

Location number	Average number of weeds per square yard in 10 paired plots	
	Fertilized	Unfertilized
1	56	54
2	299	259
3	3	4
4	148	95
5	273	214
6	604	573
Average	231	200

RESULTS AND DISCUSSION

Weed Counts

The comparative weed counts under the two levels of soil fertility are summarized in Table 1. The slightly higher average number of weeds per square yard in the fertilized portions of most fields might imply that weeds have benefited from fertilizer treatment. However, because of the wide variations in number of weeds between replicates this apparent increase in weed germination and growth was not statistically significant.

Weeds found in the six fields were almost exclusively annual species. In the Roblin area (locations 1 to 4) wild oats (*Avena fatua* L.) and wild mustard (*Sinapsis arvensis* L.) were the predominant weeds, while in the Portage la Prairie area (locations 5 and 6) wild oats (*Avena fatua* L.), wild buckwheat (*Polygonum convolvulus* L.) and hemp nettle (*Galeopsis tetrahit* L.) were most prevalent. In only a few plots were perennial weeds found.

Effect of Fertilization and Weed Removal on Wheat Yields

In some fields response to fertilizer treatment became apparent as early as the 2- to 3-leaf stage of wheat growth, at which time wheat in the fertilized plots, under both weedy and weed-free conditions, was about 2 inches taller than wheat in corresponding unfertilized plots. Although this differential in growth became less apparent during advanced stages of vegetative growth, the response to fertilizer was obvious again at maturity. At locations 4, 5 and 6 fertilized plots matured about 3 days earlier than unfertilized plots, while at location 1 maturity of wheat was advanced by about 6 days as a result of fertilizer treatment. In the other fields, locations 2 and 3, response of wheat to fertilizer was not evident at any stage of crop development. Inherent high fertility of the soil at these two locations was likely responsible for the lack of response to fertilizer treatment.

Data in Table 2 indicate that the average yields from fertilized plots were consistently higher than yields in unfertilized plots; at four of the locations the increases were significant ($P = .01$). Wheat yields were also consistently higher in weed-free plots as compared with wheat yields from weedy plots. Because of the comparatively low weed counts at locations 1 and 3, increases in yield from weed removal were not significant at these two locations. On the average, yield increases as a result of fertilizer treatment were similar to the increases resulting from weed removal.

Average wheat yields invariably were highest where fertilizer application and weed removal were combined and lowest in plots receiving no treatment. However, the beneficial effects of fertilization and weed removal were not completely additive. Only in two fields did the actual increase obtained from fertilization and weed removal combined approximate the theoretical increase calculated by summing the separate increases.

TABLE 2. — THE EFFECT OF FERTILIZER APPLICATION AND WEED REMOVAL ON THE YIELD (BUSHELS PER ACRE) OF WHEAT ON SIX MANITOBA FARM FIELDS, 1958

Location number	Fertilized plots		Unfertilized plots		Average yield increase resulting from:		
					Fertilization	Weed removal	Fertilization plus weed removal
	Weed-free	Weedy	Weed-free	Weedy			
1	37.4	36.1	30.4	28.6	7.5**	1.8	8.8
2	31.2	28.5	29.7	21.9	3.9	7.8**	9.3
3	53.3	49.5	51.3	50.0	−0.5	1.3	3.3
4	34.9	31.3	29.7	21.4	9.9**	8.3**	13.5
5	44.7	37.0	35.4	25.1	11.9**	10.3**	19.6
6	46.9	39.9	37.2	25.6	14.3**	11.6**	21.3
Average	41.4	36.6	35.6	28.8	7.8	6.8	12.6

**Significant at the 1 per cent level of probability

TABLE 3. — LOSSES IN WHEAT YIELDS DUE TO WEED COMPETITION IN FERTILIZED AND UNFERTILIZED PORTIONS OF SIX FARM FIELDS, 1958

Location number	Fertilized plots		Unfertilized plots	
	Losses due to weeds		Losses due to weeds	
	bu./ac.	per cent	bu./ac.	per cent
1	1.3	3.5	1.8	5.9
2	5.4**	17.3	7.8**	26.3
3	3.8	7.1	1.3	2.5
4	3.6	10.3	8.3**	27.9
5	7.7**	17.2	10.3**	29.1
6	7.0**	14.9	11.6**	31.2
Average	4.8	11.7	6.8	20.5

**Significant at 1 per cent level of probability

Losses due to weed competition in the fertilized plots were consistently lower than in adjacent unfertilized plots. Data are presented in Table 3. The average loss for the six fields was 4.8 bushels per acre (11.7 per cent) in the fertilized plots as compared to an average loss of 6.8 bushels per acre (20.5 per cent) in unfertilized plots. This indicates that losses due to weed competition can be reduced considerably by the use of a commercial fertilizer with the grain crop. Moreover, crop response to the fertilizer treatment was greater under weedy conditions than under weed-free conditions. Average yield increases resulting from fertilization were 7.8 bushels per acre under weedy conditions as compared to 5.8 bushels per acre under weed-free conditions.

Effect on the Protein Content of Wheat

The protein content of wheat was generally highest in those plots from which weeds had been removed (Table 4). The increases in protein content resulting from weed removal were significant at three locations. These results are rather striking, for weeds were most numerous at the three locations where significant increases occurred. However, applications of the commercial fertilizer did not result in consistent increases in the protein content. In fact, at two locations, significant reductions in protein content occurred as a result of fertilizer treatment.

Results of this study are in agreement with the observations of Hunter *et al.* (9) and Hutchison (10) who reported that significant increases in yield of wheat from fertilizer application sometimes resulted in reductions in protein content. It would appear that applications of a commercial fertilizer to a wheat crop should be accompanied by weed control practices to maintain the protein content at a high level.

TABLE 4. — THE EFFECT OF FERTILIZER APPLICATION AND WEED REMOVAL ON THE PROTEIN CONTENT (PER CENT) OF WHEAT ON SIX FARM FIELDS, 1958

Location number	Fertilized plots		Unfertilized plots		Average protein increase resulting from:		
					Fertilization	Weed removal	Fertilization plus weed removal
	Weed-free	Weedy	Weed-free	Weedy			
1	13.05	13.27	12.92	12.93	.34	−.01	.12
2	11.57	11.00	11.77	11.23	−.23	.54**	.34
3	13.23	13.25	13.21	13.00	.25	.21	.23
4	12.48	12.35	13.28	12.92	−.57**	.36	−.44
5	13.21	12.83	13.18	12.72	.11	.46**	.49
6	14.50	14.17	14.96	14.56	−.39**	.40*	−.06
Average	13.01	12.81	13.22	12.89	−.08	.33	.12

*Significant at 5 per cent level of probability
**Significant at 1 per cent level of probability

Effect on Bushel Weight of Wheat

Average bushel weights of wheat from fertilized plots were slightly higher than from plots to which fertilizer had not been applied. However, these increases were not significant. McNeil and Davis (12) also reported that the bushel weight of a number of wheat varieties was not affected by fertilizer application. Similarly the bushel weight of wheat was not affected by weed competition. Since average weed densities recorded for the six locations varied from 3 to 604 weeds per square yard where a commercial fertilizer was applied, and from 4 to 573 weeds per square yard where fertilizer was not applied, it appears that the bushel weight of wheat was not influenced by the degree of weediness under either level of soil fertility. Burrows and Olson (2) have also reported that the bushel weight of wheat was not affected by competition from densities of wild mustard ranging between 0 and 200 mustard plants per square yard.

CONCLUSIONS

The results of these experiments indicate that monoammonium phosphate fertilizer (11-48-0) applied directly with seed grain can reduce considerably the yield losses caused by weed competition. Increases in yields as a result of fertilizer treatment were sometimes associated with decreases in the protein content of harvested grain. However, these reductions in protein content could be offset, to a certain extent, by weed control. Thus, on the basis of these results, it can be concluded that application of a commercial fertilizer and removal of weeds are practices which may be combined advantageously to increase crop yields and, at the same time, maintain the protein content at a high level. It should be pointed out that, although removal of weeds in this study was accomplished through "hand weeding", similar results would probably be obtained when weeds are removed from the crop by an appropriate herbicidal treatment.

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POWDERY MILDEW RESISTANCE IN STRAWBERRY PROGENIES

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ABSTRACT

The effect of various parents on the degree of powdery mildew resistance in strawberry progenies was studied. Puget Beauty parentage, compared with Siletz, Surecrop, Talisman, Magoon, or Stelemaster parentage, gave a highly significant increase in the mean resistance rating. British Sovereign parentage, compared with Northwest or Agassiz parentage, gave a significant increase in the mean resistance rating. Puget Beauty was the only parent to give relatively large numbers of seedlings immune or resistant to powdery mildew. Siletz was as resistant to the disease as Puget Beauty, but did not transmit this resistance to its progeny. Selections immune or resistant to powdery mildew will be used in the strawberry breeding program at Agassiz.

INTRODUCTION

In many years, powdery mildew, caused by *Sphaerotheca macularis* (Fr.) Magn., is a serious disease on strawberries grown in the coastal areas of British Columbia. Of five commercially important varieties, British Sovereign, Northwest, and Agassiz show moderate to severe susceptibility while Siletz and Puget Beauty show resistance or slight susceptibility. Although no precise data are available on the extent of yield reduction from the disease, severely infected plants are much reduced in vigour. When severe epiphytotics occur, comparisons of Siletz or Puget Beauty with British Sovereign, Northwest, or Agassiz indicate that resistance is desirable irrespective of whether a regular spray program is followed.

Miller and Waldo (4), Orchard and van Adrichem (5), and Daubeny (2) have screened strawberry varieties, seedlings and selections of *Fragaria* species for powdery mildew resistance. Daubeny also observed relative differences in resistance among seedling populations. Harland and King (3) postulated that powdery mildew resistance in diploid *Fragaria vesca* selections was dependent on two recessive genes, but that inheritance was complicated by a cytoplasmic factor.

In 1959, the cross of Siletz x Puget Beauty, compared with 16 other crosses, gave a large number of seedlings which remained free from powdery mildew (2). These seedlings were observed in the greenhouse while they were being screened for red stele resistance. Some seedlings from most of the crosses were selected for resistance to the latter disease, regardless of powdery mildew resistance, and five plants of each were placed in the field during the spring of 1960. The natural infestation of powdery mildew was severe during the ensuing summer and readings for relative resistance were made. For the selected seedlings, the correlation coefficient between the greenhouse readings for relative resistance and the field readings for relative resistance was highly significant ($r = +.63$, $N = 193$). This indicated the value of selecting for powdery mildew resistance in strawberry seedlings growing in the greenhouse.

The purpose of the present study was to determine the effect of various quality parents and red stele resistant parents on the degree of powdery mildew resistance in strawberry progenies growing in the greenhouse.

MATERIALS AND METHODS

The seedlings examined for powdery mildew resistance were derived from progenies of 20 crosses selfed Agassiz and selfed Puget Beauty. The crosses comprised a quality parent, one of Agassiz, British Sovereign, or Northwest and a red stele resistant parent, one of Siletz, Talisman, Stelemaster, Puget Beauty, Surecrop, Magoon, or a clone of *Fragaria chiloensis* from Nelscott, Oregon. Seedlings, derived from the cross of two clones of British Sovereign, were used to indicate the severity of both powdery mildew and red stele.

Seedlings of the crosses, with the exception of those involving the *F. chiloensis* clone, were planted in a split-split-plot design (6) of four replications, each in a separate bench of red stele infested soil. Additional seedlings from many of the crosses, those with *F. chiloensis* parentage, and those of selfed parentage, were planted in solid blocks. All seedlings were planted 4 inches apart during the latter part of August, 1960.

The split-split-plot design was originally set up to evaluate the contribution of each parent to red stele resistance. Each of the main plots, in a replication, contained a different quality source as one parent. Each of the sub-plots, within a main plot, contained a different red stele resistant source as one parent. Each sub-plot was divided to contain each of the two members of the reciprocal cross, the quality parent and the red stele resistant parent. Such a design was also effective for evaluating the contribution of individual parents to powdery mildew resistance.

All seedlings were rated for relative resistance to powdery mildew during the first 2 weeks of September. The rating system used was previously described by Daubeny (2) and based upon that used by Miller and Waldo (4). A rating of 10 meant no mildew; 9, a trace of mildew but no leaf roll; 8, a small amount of mildew with slight leaf roll; 7, mottling and leaf roll; 6, much leaf roll and injury to the lower leaf surface; 5, much leaf roll accompanied by severe necrosis and possible leaf loss. Few seedlings were rated lower than 5 and none was rated as 1. Dead seedlings were not included in the summarization of the ratings since it was not possible to attribute the condition directly to powdery mildew. Seedlings rated 10 were re-examined 2 weeks later and, where necessary, ratings were adjusted.

RESULTS

Powdery mildew infestation varied somewhat among the British Sovereign indicator seedlings (Table 1). Within a replication there was no apparent relationship between severity of the disease on the indicator seedlings and severity on adjacent seedlings of the other progenies. It is likely, therefore, that the within replicate variation among the indicator seedlings can be attributed to genetic segregation. The readings in replication IV and also in the non-replicated planting showed a more severe infestation of the disease. The increased severity was also noted on the other progenies in these plantings and was probably due to environment. The data suggest the variations in powdery mildew infestation were such that the readings on the other progenies were valid with respect to relative resistance and susceptibility.

TABLE 1. — VARIATIONS IN THE REACTION OF BRITISH SOVEREIGN INDICTOR SEEDLINGS TO POWDERY MILDEW INFECTION IN THE GREENHOUSE

Replicate	Number of seedlings	Percentage with rating of					
		5	6	7	8	9	10
I	106		15.1	57.5	22.6	4.7	
II	110		7.3	58.2	24.5	9.1	
III	91		5.5	68.1	15.4	11.0	.9
IV	91	15.4	24.2	50.5	4.4	5.5	
Non-replicated planting	215	13.9	40.0	41.9	2.8	1.4	
Total	613	7.2	22.3	52.7	12.2	5.4	.2

TABLE 2. — VARIATIONS IN THE REACTION OF STRAWBERRY PROGENIES TO POWDERY MILDEW INFECTION IN THE GREENHOUSE

Progeny	Percentage with rating of							No. of seedlings	Mean resistance rating
	4	5	6	7	8	9	10		
Siletz x Agassiz		4.0	24.0	40.2	15.3	16.0	.4	445	7.16
Siletz x Brit. Sov.		3.8	28.2	50.4	12.5	5.0	.2	504	6.87
Siletz x Northwest	.2	10.2	39.4	38.8	8.8	2.4	.3	627	6.62
Siletz x Puget Beauty	.2	.7	12.8	23.5	8.8	18.1	35.8	430	8.38
Talisman x Agassiz		2.3	32.4	48.0	8.6	8.3	.3	302	6.89
Talisman x Brit. Sov.		2.0	19.2	45.1	15.8	16.5	1.3	297	7.30
Talisman x Northwest		1.6	37.0	48.8	6.3	5.9	.4	254	6.79
Stelemaster x Agassiz		2.5	53.7	37.6	3.7	2.5		162	6.50
Stelemaster x Brit. Sov.		4.5	26.6	52.4	10.3	6.0	.2	399	6.87
Stelemaster x Northwest		4.2	29.6	54.0	8.2	4.0		378	6.78
Puget Beauty x Agassiz		.4	16.2	26.0	7.4	19.6	30.3	499	8.21
Puget Beauty x Brit. Sov.		1.3	7.4	27.7	7.1	18.8	37.8	394	8.48
Puget Beauty x Northwest		1.7	10.1	30.0	11.5	13.4	33.3	357	8.25
Surecrop x Agassiz		3.4	36.0	49.2	8.6	2.7		441	6.71
Surecrop x Brit. Sov.	.2	4.0	24.5	37.6	13.3	20.1	.2	428	7.21
Surecrop x Northwest		9.3	38.3	29.0	11.0	11.6	.8	507	6.80
Magoon x Agassiz		6.6	45.7	39.6	5.2	2.9		556	6.52
Magoon x Brit. Sov.		6.5	24.8	50.5	10.6	7.4	.2	432	6.88
Magoon x Northwest		1.6	34.8	52.1	9.8	1.6		376	6.75
Brit. Sov. x *F. chiloensis*			26.1	57.2	8.0	8.7		138	7.00
Agassiz selfed	1.0	7.6	42.5	42.8	2.9	3.1		381	6.48
Puget Beauty selfed	.4		6.3	24.1	4.3	25.7	39.1	253	8.66

Progeny having Puget Beauty parentage had a relatively large proportion of seedlings rated 10 or 9 for powdery mildew resistance (Table 2). Also, the mean resistance rating for these seedlings was greater than that recorded for seedlings without Puget Beauty parentage.

In the field, Siletz was at least as resistant to powdery mildew as Puget Beauty. However, the progenies of Siletz parentage contained fewer resistant seedlings (Table 2), than those of Puget Beauty parentage. This suggests that the factors for resistance in Siletz and Puget Beauty have a different genetic basis.

TABLE 3. — THE EFFECT OF PARENT ON MEAN POWDERY MILDEW RESISTANCE RATING IN STRAWBERRY PROGENIES

Parents	Mean resistance rating			Number of seedlings
		5%	1%[1]	
Quality parent:				
British Sovereign	7.33	a	b	2178
Northwest	7.12	b	b	2081
Agassiz	7.08	b	b	2001
Disease resistant parent:				
Puget Beauty	8.35	a	a	1009
Siletz	7.10	b	b	1146
Surecrop	7.07	b	b	1154
Talisman	6.94	b	b	853
Magoon	6.89	b	b	1110
Stelemaster	6.73	b	b	898
Maternal parent:				
Quality	7.20	b	b	3637
Disease resistant	7.16	b	b	2623

[1]Duncan's multiple range test. Figures, within each parental type, with different letter are statistically different at the indicated significance levels.

In those crosses in which Puget Beauty did not occur, most of the seedlings were rated 6 or 7 for resistance to powdery mildew (Table 2). In contrast, seedlings with Puget Beauty parentage largely fell into two classes, 9 or 10 and 6 or 7; these groupings indicated segregation into resistant and susceptible lines. The nature of the frequency distribution suggests that the inheritance of resistance to powdery mildew in the cross of a resistant parent and a susceptible parent is controlled by relatively few genes. Further crosses will be studied, however, before making determinations on the actual number of genes involved.

Puget Beauty, compared with any of the other red stele resistant varieties, conferred a highly significant increase in the degree of powdery mildew resistance in its progenies (Table 3). Siletz or Surecrop parentage, compared with Talisman, Magoon or Stelemaster parentage, increased the degree of resistance in their respective progenies but not to the significant level. British Sovereign, compared with Agassiz or Northwest, gave a significant increase in the degree of resistance in its progenies.

DISCUSSION

Puget Beauty and seedlings with Puget Beauty parentage, selected for powdery mildew resistance, will be useful in the future breeding program. The fact that Siletz showed a high degree of resistance, but did not transmit this to its progenies, indicates that the plant breeder cannot effectively choose resistant parents unless they have been evaluated in crosses. It is suggested that powdery mildew resistance in the cultivated strawberry is controlled by relatively few genes. This coincides with Harland and King's (3) observation that powdery mildew resistance in diploid *Fragaria vesca* selections is controlled by two genes. These genes are described as recessive, which agrees with the results obtained when Siletz was used as the

resistant parent, but not when Puget Beauty was used. The genes for resistance in Puget Beauty appeared to be dominant. It may be that the relative dominance or recessiveness of resistance is complicated by the octoploid nature of the cultivated strawberry. The establishment of selections, homozygous for resistance or immunity to the disease, should facilitate determination of the nature of resistance and the actual number of genes controlling it.

In contrast with Harland and King's results, the maternal parent had no effect on powdery mildew resistance in the progenies studied (Table 3). It is possible that cytoplasmic effects on powdery mildew resistance are limited to certain parents. This possibility was demonstrated in apple breeding studies in which Brown (1) found no effect of maternal parent on powdery mildew resistance, but cites German work, with different progenies, in which the maternal parent had an effect on resistance.

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ASSOCIATION OF FALL GROWTH HABIT AND WINTER SURVIVAL IN ALFALFA[1]

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ABSTRACT

Growth following cutting in early September and winter survival of first-year plant populations of several varieties of alfalfa were studied at Madison, Wisconsin. Plant populations of varieties with high winter hardiness produced, during the shortening daylengths and cooler nights of autumn following early September cutting, top growth of short over-all height, a high percentage of short plants, and a low percentage of very tall plants. The reverse was true of the less hardy varieties.

Highly significant correlations were obtained between per cent winter injury sustained during the seedling winter with the per cent of extra tall plants (0.95), the average height of all plants (0.94), and the per cent of short plants (−0.81) measured the previous fall.

Plants derived from seed of crosses among extra tall, upright plants of Vernal alfalfa were uniformly tall and sustained much winter injury, while plants from crosses among short, spreading plants were uniformly short and sustained very little winter injury. The plants derived from seed of intermediate plants were intermediate in performance between the other two crosses, and they performed more nearly like Vernal alfalfa.

Winter loss estimates based on rating each plant for injury measured more precisely the differences in winter survival among varieties than basing winter losses on only the number of dead plants.

INTRODUCTION

It has been known for some time that alfalfa varieties which go dormant early and produce little top growth during the fall in the north generally are more winter hardy than varieties that continue to grow during the fall months. This daylength response has been used as a means of distinguishing between hardy and non-hardy varieties and the observations have been made usually in mass-seeded plots or rows. More critical information is needed as to the reliability of fall growth (growth under short daylengths) as an indicator of winter survival value. Such information would aid the plant breeder in selecting for hardiness, in developing trueness-to-type tests of variety seed increases, and in evaluating new breeding strains and varieties. The current work was initiated on individual plant populations of several alfalfa varieties varying in hardiness to ascertain more precisely the association of fall growth habit and winter survival.

LITERATURE REVIEW

As early as 1904, Blinn (1) noted that there were detectable differences in growth habit among plants from hardy and non-hardy varieties. Beginning in 1918, Graber (4,5) found that the amount of top growth produced by new field seedings following cutting in early September could be used as an aid in distinguishing varieties of alfalfa. Graber used this character to help locate and develop seed supplies of dependable Grimm for Wisconsin during the period when most of the seed available was Common and before much Grimm was produced under certification regulations. The technique (Figure 1) has been useful over the years to differentiate varieties (4,5,16).

[1]Contribution from the Department of Agronomy, Wisconsin Agr. Expt. Station. Published with approval of the Director, Wisconsin Agr. Expt. Station.
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In 1921, Oakley and Westover (9) concluded that the amount of fall top growth produced was a daylength response. They showed that hardy and non-hardy varieties could be distinguished in the seedling stage by the height of the top growth produced when grown under short daylengths in the greenhouse or when established during autumn in the field. Others also have shown this differential in vegetative growth under short daylengths (3, 11).

The fall growth technique was used at Wisconsin beginning in 1945 to determine whether genetic changes had occurred in Ranger alfalfa when certified seed was produced in southern latitudes outside of its area of adaptation (2,12,13,14). Since mass populations in rows or plots usually cover small differences that may be present, Smith (13,14,15) began in 1952 to use spaced populations rather than mass seedings to compare the performance of different seed increases of Ranger, Vernal, and Narragansett. Spaced populations permitted appraisals among and within seed lots of these varieties from the diversity of plant types revealed. These studies indicated that plants of these varieties that grew tall and upright following early September cutting were less winter hardy than plants that were short and spreading in growth.

Nittler (7), Schonhorst *et al.* (10), and Nittler and Gibbs (8) have proposed the growing of seedling alfalfa plants in the greenhouse or growth chamber under controlled light and temperature conditions as a rapid means of distinguishing hardy and non-hardy alfalfas and their mixtures, and as a means of determining trueness-to-type of seed increases of a variety. Their results indicated that the differentials were most apparent at about 60°F. and with a 12-hour daylength.

Kohel and Davis (6) in an inheritance study involving selected F_2 and backcross$_1$ plants found analysis of variance of the data to indicate that fall growth and cold resistance, measured by laboratory electrical conductance, were not significantly associated. However, mean fall growth and mean winter survival in the field were significantly correlated (-0.54), indicating survival was associated with dormant fall growth. Also, the correlation (0.47) between mean fall growth and cold resistance, measured by laboratory electrical conductance, was significant.

MATERIALS AND METHODS

The growth habit and winter survival of several alfalfa varieties were studied in space-planted, seedling populations. Seed was sown in mid-May each year in rows 18 inches apart in five to ten replications in a randomized complete block design. The plants were blocked and thinned to about 12 to 14 inches apart in the row approximately 1 month after seeding. The average population established of each variety was from 180 to 200 plants each year. The foliage of the plants was kept free of harmful insects by frequent spraying. The area was kept free of weeds and of new seedlings from hard seeds.

TABLE 1.—AVERAGE HEIGHT OF FALL GROWTH, DISTRIBUTION OF INDIVIDUAL PLANT HEIGHTS, AND AVERAGE PERCENTAGE OF WINTER INJURY IN SEEDLING YEAR[1]

Variety	Average height of all plants, inches	Per cent of plants in height groups				Per cent winter injury[2]
		Short	Medium	Tall	Extra tall	
DuPuits	10.88 a	0 a	2 a	7 bc	91 a	79 b
Caliverde	9.72 b	1 a	4 a	12 de	83 b	99 a
Alfa	9.58 b	1 a	3 a	17 ef	79 b	61 d
Buffalo	8.43 c	1 a	9 b	30 hi	60 c	75 b
Lahontan	8.27 c	1 a	14 c	26 gh	59 c	69 c
Ranger	6.90 d	7 b	27 de	32 hi	34 d	38 e
Atlantic	6.62 d	10 b	27 de	34 hi	29 d	40 e
Cossack	5.76 e	20 cd	34 ef	27 ghi	19 e	39 e
Grimm	5.66 e	19 c	34 ef	30 hi	17 e	26 f
Narragansett	5.06 f	26 d	38 f	22 fg	12 f	18 g
Culver	4.72 f	38 e	35 ef	18 f	9 f	25 f
Vernal	4.70 f	36 e	34 ef	22 fg	8 f	23 f
Ladak	3.61 g	62 f	24 d	11 cd	3 g	12 h
Rhizoma	3.46 g	62 f	30 de	5 b	3 g	11 h
Teton	1.68 h	97 g	3 a	0 a	0 h	4 i
C.V. %	6.8	18	21	19	14	12

[1]Average results from 1956 and 1958 seedings. Any two means followed by same letter are not significantly different, and *vice versa*
[2]Average based on each plant rated from 0% (uninjured) to 100% (dead)

FIGURE 1. Differences among alfalfa strains established in solid rows in the amount of fall growth produced following cutting in early September as accentuated by a light snowfall.

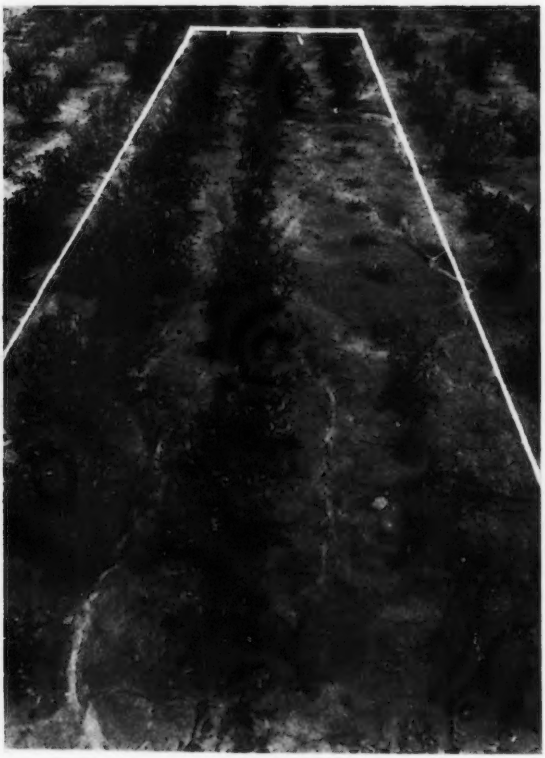

FIGURE 2. Differences in winter survival among populations derived from seed of a cross among short, spreading plants (*left*), among intermediate plants (*centre*), and among extra tall, upright plants (*right*) from Vernal alfalfa.

In order to obtain reliable winter survival data, it is necessary that plants maintain their natural relationship with the soil surface. For this reason, plants were established from seed in the field and not from transplants. Cultivation was not practised so that soil would not be thrown up around the crowns adding unnatural insulation over winter. Weeds were controlled by scraping the soil surface.

On September 9, ± 1 day, the plants were cut with a small mower and then trimmed uniformly to a 1½-inch height with a whirlwind mower. Any stems not removed were cut with a sharp hoe. All of the succeeding growth, thereby, arose from the terminal buds of unelongated rhizomes or from other buds of the crown. Thus, the regrowth was produced under the shortening daylengths and cooler nights of autumn.

The height of each individual plant was determined in early October prior to frost by measuring the height above the soil surface of the terminal bud on the tallest stem of each plant without disturbing the natural direction of stem growth. The plant height data obtained each fall separated plants into four groups: short, medium, tall, and extra tall. In 1956, plants categorized as *short* were those from 0 to 2.9 inches tall, *medium* from 3.0 to 4.9, *tall* from 5.0 to 6.9, and *extra tall* 7 inches and taller, respectively. The range of heights for each group was increased by 2 inches in 1958 and 4 inches in 1959, so that approximately the same percentages occurred in each group in the Vernal and Ranger varieties. The percentage of plants in each height group was determined, and the percentages were transformed to $\sqrt{\%}$ for statistical analyses.

The top growth was removed again in mid-October. This prevented differentials in snow accumulation and increased the possibility of winter injury. Winter injury estimates were made the following spring when the stems of uninjured plants had grown to about 6 or 7 inches. The injury of each plant was rated on the basis of 100 per cent for a dead plant and 0 per cent for a vigorous and uninjured plant. Killing appeared to be the result primarily of the exposure of plants to low air temperatures during periods of the winters when there was no snow cover.

Seedling populations of 15 alfalfa varieties were studied in 1956, 1957, and in 1958. The seedings were made in five replications each year. The growth habit of plants was not ascertained in the 1957 population because of the death of some plants from an infection of crown and root rot caused by *Fusarium roseum* and *Fusarium oxysporum*. Diseased plants were eliminated and winter survival readings were ascertained on the remaining plants.

Seedling populations of crosses made within growth types of Vernal alfalfa were studied in 1959. Following early September cutting in 1956 and 1957, 14 extra tall and upright-growing plants, 18 short and spreading plants, and 15 intermediately tall and intermediately spreading plants from Utah Foundation Vernal alfalfa were propagated by stem cuttings. The 14 tall plants were planted together in isolation for seed production, as were

also the 18 short plants and the 15 intermediate plants. Seed was harvested separately from each plant and the seed used was a mixture of an equal amount by weight from each plant. Seed of each of the three crosses was seeded in the spring of 1959 in 10 replications.

TABLE 2.—CORRELATION COEFFICIENTS BETWEEN CERTAIN PLANT MEASUREMENTS BASED ON AVERAGE RESPONSES OF 15 ALFALFA VARIETIES

Plant measurements	Correlation[1]
Average height of all plants and % short plants	−0.90**
Average height of all plants and % medium plants	−0.53*
Average height of all plants and % tall plants	0.24
Average height of all plants and % extra tall plants	0.96**
Average height of all plants and % winter injury	0.94**
% short plants and % medium plants	0.16
% short plants and % tall plants	−0.61*
% short plants and % extra tall plants	−0.92**
% short plants and % winter injury	−0.81**
% medium plants and % tall plants	0.43
% medium plants and % extra tall plants	−0.72**
% medium plants and % winter injury	−0.62*
% tall plants and % extra tall plants	0.04
% tall plants and % winter injury	0.16
% extra tall plants and % winter injury	0.95**

[1]**Significant at 1% level; * significant at 5% level (n = 15). Results based on 2 years, 1956 and 1958

TABLE 3.—AVERAGE PERCENTAGE OF WINTER INJURY DURING THE FIRST WINTER IN VARIOUS PLANT HEIGHT GROUPS[1]

Varietal fall growth response	Plant height groups			
	Short	Medium	Tall	Extra tall
Tall-growing: DuPuits, Caliverde, Alfa, Buffalo, Lahontan				
1957	41	67	68	82
1959	64	71	66	80
Av.	52	69	67	81
Intermediate-growing: Ranger, Atlantic, Cossack, Grimm, Narragansett				
1957	21	35	52	72
1959	12	13	19	29
Av.	16	24	35	50
Short-growing: Teton Rhizoma, Ladak, Vernal, Culver				
1957	12	25	35	56
1959	4	13	22	32
Av.	8	19	28	44

[1]Winter injury based on each plant rated 0% (uninjured) to 100% (dead). Average results from plant populations established in 1956 and 1958

RESULTS AND DISCUSSION

Differentials in Performance among Varieties

A diversity of plant types became apparent in the autumn growth of each variety which is not observable in the spring or in the regrowth following cutting during the summer. Some plants responded by producing tall and erect stems while the stems of other plants grew long or short but prostrate. Such characteristics usually are obscured in the competition of thickly sown rows or plots.

The performance of 15 varieties averaged over 2 years is shown in Table 1. DuPuits, Caliverde, Alfa, Buffalo, and Lahontan were varieties characterized by plant populations that had a tall average height, a small percentage of short plants, a high percentage of tall plants, and severe winter injury. In contrast, Teton, Rhizoma, Ladak, Vernal, and Culver were the opposite in plant type composition and winter injury. These varieties were characterized by a short average height, a high percentage of short plants, a low percentage of tall plants, and little winter injury. Ranger, Atlantic, Cossack, Grimm, and Narragansett were more or less intermediate in plant type composition.

A high correlation existed between certain plant measurements (Table 2). Of particular interest are the highly significant correlations between the percentage of winter injury sustained during the seedling winter with the percentage of extra tall plants (0.95), the average height of all plants (0.94), and the percentage of short plants (-0.81) measured the previous fall.

Winter Hardiness among Plant Types

The varietal plant populations afforded an opportunity to study the association of fall growth with winter survival within varieties. In order to simplify the data, the varieties were placed into three categories based on their general fall growth response: tall-growing, intermediate, and short growing. The data (Table 3) indicated that, regardless of the fall growth response or winter hardiness of the varieties, winter injury within the varieties was least in the short plants and was progressively more severe as plant height increased. These results agree with previous observations made with Ranger and Vernal (13,15). Thus, fall growth habit can aid the alfalfa plant breeder in selecting hardy plant material from within varietal populations.

Performance of Progeny from Seed of Tall, Intermediate, or Short Vernal Plants

The performance of plants derived from seed of crosses within growth habit groups of Vernal alfalfa is shown in Table 4 along with the performance of Vernal alfalfa itself. It is apparent that the seed from crosses among extra tall, upright plants produced a plant population that was quite uniformly tall and sustained a high level of winter injury (Figure 2). In contrast, seed from crosses among short, spreading plants produced a plant population that was quite uniformly short and sustained very little winter injury. The plant population derived from seed of crosses among inter-

TABLE 4.—PERFORMANCE OF PLANTS DERIVED FROM CROSSES WITHIN GROWTH HABIT GROUPS OF VERNAL ALFALFA[1]

Plant growth type	Average height of all plants[2], inches	Per cent of plants in height groups				Per cent winter injury[4]
		Short	Medium	Tall	Extra tall	
Extra tall, upright	10.32 a	5 a	16 b	32 c	47 c	65 d
Intermediate	7.51 b	31 b	45 d	20 b	4 ab	37 b
Short, spreading	4.48 c	92 d	7 a	1 a	0 a	17 a
Vernal[2]	7.20 b	44 c	30 c	18 b	8 b	43 c
C.V. %	6.4	19	24	27	37	7

[1]Measurements of spaced populations in seedling year, 1959
[2]Average of 6 commercial seed lots
[3]Any two means followed by same letter are not significantly different, and *vice versa*
[4]Average based on each plant rated from 0% (uninjured) to 100% (dead)

TABLE 5.—WINTER LOSSES ESTIMATED BY TWO METHODS DURING 3 YEARS, 1956-58[1]

Variety	Per cent winter injury, based on rating each plant 0 to 100	Per cent winter killing, based on number of dead plants
Caliverde	97 a	97 a
DuPuits	81 b	73 b
Buffalo	76 bc	67 bc
Lahontan	71 c	61 c
Alfa	64 d	51 d
Atlantic	39 e	25 e
Cossack	36 e	25 e
Ranger	36 e	19 ef
Grimm	26 f	15 fg
Culver	25 f	14 fg
Vernal	19 g	8 gh
Narragansett	16 g	7 hi
Ladak	10 h	5 hi
Rhizoma	8 h	3 i
Teton	2 i	0 j
C.V. %	12	18

[1]Any two means followed by the same letter are not significantly different, and *vice versa*

mediate plants was intermediate in performance between the other two crosses, and it performed more nearly like Vernal alfalfa.*

These data again show the close association between fall growth habit and winter survival and the heritability of this character. Also, there may be an association of these characters with seed production. It was not possible to substantiate this with these plants since seed was produced in different years. However, it is quite likely that the high seed-producing

*No clear-cut differences in bacterial wilt reaction were found among the crosses and Vernal in an artificially inoculated field test conducted in 1960.

plants in a population are the tall and less hardy plants, as the results of Canode (2) with Ranger alfalfa suggest. If this is the case, plants selected for high seed production from a northern-adapted variety growing in a southern latitude with short summer daylengths are likely to be among the less hardy plants in the population.

Winter Injury Estimates

Winter injury in the study of varieties was estimated each spring by rating each plant. This practice was used in order to allow each plant to contribute to the averages for a variety. A much more rapid estimate of winter losses was based on the number of dead plants in the spring. This practice does not take into consideration the amount of injury sustained by the plants that survived the winter. A comparison of these two methods of measuring winter losses (Table 5) over a period of 3 years indicated that varieties were ranked in the same order by either method. However, differences among varieties were measured more precisely when each plant in the population was rated as to amount of injury it sustained.

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PENETRATION OF AND PERSISTENCE IN SOIL OF THE HERBICIDE 2-CHLORO-4,6-BIS(ETHYLAMINO)-S-TRIAZINE (SIMAZINE)[1]

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ABSTRACT

A study was made of the soil penetration and persistence of Simazine, applied in May, 1958, to a fallow soil at rates ranging from 0.5 to 20 lb./ac. (active). Residual concentrations at 0-1 inch, 1-2 inches, 2-4 inches, 4-6 inches, and 6-8 inches, were determined by chemical analysis.

At the time of the final 1958 sampling (96 days after application) it was found that a much greater proportion of the Simazine was present in the lower layers in those plots receiving the lighter applications than in those plots receiving the heavier applications, where most was still concentrated in the 0-1 inch layer. However, 1 year after application this trend was much less marked. At that time the average distribution among the 0-1, 1-2, 2-4, 4-6, and 6-8 inch layers was 64.1 per cent, 19.1 per cent, 14.5 per cent, 1.7 per cent, and 0.6 per cent, respectively. Two years after application the greatest concentration of Simazine was still in the 0-1 inch layer. In general, the total of the combined amounts present in the second and third layers was approximately equal to the total of the amounts present in the 0-1 inch layers. Very little was present in the two lower layers.

At the time of the final first season sampling an average of 34.9 per cent of the applied Simazine was still present; but, by the end of the first year this value had dropped to 8.3 per cent, and by the end of the second year the average percentage present was only 2.7 per cent.

INTRODUCTION

The herbicide 2-chloro-4,6-bis(ethylamino)-s-triazine, commonly known in America under the trade name Simazine, is of importance for weed control in crops and for soil sterilization purposes. Although so far predominantly used as a pre-emergence herbicide in corn, it shows promise for weed control in several such other crops as asparagus, strawberries, potatoes, tomatoes, gladioli, raspberries, blueberries, cranberries, sugarcane, pineapple, grapes, and fruit orchards (but not stone fruits) and woody species of ornamentals and nursery crops. While corn is quite resistant to this herbicide, various other crops such as oats and small-seeded legumes are much more susceptible to injury. Because of the possible adverse effect on succeeding crops in the rotation, following applications of Simazine for weed control in corn, and owing to its low water solubility (5 p.p.m. at 20°C.) and relatively long-term herbicidal activity, questions concerning rate and extent of soil penetration and persistence in the soil are quite important. Its persistence is also of importance concerning its use as a non-selective and industrial herbicide.

The present study was undertaken in order to obtain information on the rate and extent of soil penetration and the persistence of Simazine applied at rates ranging from 0.5 to 20 pounds active/acre in a soil of intermediate texture and organic matter content and under Ontario conditions. Residual concentrations have been determined by chemical analysis. Observations have also been made on the control of certain weeds, and some use has been made of fall wheat and oats as indicator crops.

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The majority of studies have involved the growth of indicator crops to determine the time required for the herbicide to drop below the critical concentration for plant growth (1, 3, 6, 7). While the use of plant indicator methods is practical, it is nevertheless indirect and is desirably complemented by direct chemical analyses.

In some instances the climatic conditions under which Simazine studies were, and are being, conducted are very different to those prevailing in Ontario. The climatic conditions in Florida, where Scudder (6) is conducting very extensive studies, are scarcely comparable to the cooler soil temperatures and long winters of Ontario. Amount of rainfall is, of course, an important climatic factor.

MATERIALS AND METHODS

The experiment was conducted on the Field Husbandry Department plot area, Ontario Agricultural College. A fallow soil, classified as Guelph loam, cultivated just previous to the Simazine application, was used. On May 24, 1958, applications of 50W commercial Simazine were made on plots (15 feet x 24¾ feet and 1.36 square rods in area) at rates of 1, 2, 4, 12, 20, and 40 pounds per acre (equivalent to 0.5, 1, 2, 6, 10, and 20 pounds of active ingredient). There were two replications of each treatment. The soil was sampled twice during the first season. In 1959 and 1960 it was sampled during May, 1 and 2 years, respectively, after the setting out of the experiment. Sampling depths were 0-1 inch, 1-2 inches, 2-4 inches, 4-6 inches, and 6-8 inches, from 30 to 40 cores being taken from each plot per sampling.

A colorimetric method developed by the Geigy Chemical Corporation* was used for the chemical determination of residues in the soil samples. The procedure involves extraction of the Simazine from the soil with chloroform followed by washing of the extract with dilute alkali and acid to eliminate materials which interfere in the ultraviolet. The Simazine is then hydrolyzed by shaking with 50 per cent sulphuric acid, whereupon the hydroxy compound is transferred to the aqueous phase. The aqueous solution is then read at 240 mμ. Blank determinations were run on the soils of the control plots and the results from the treated samples corrected accordingly.

A "Recovery Correction Factor" was determined by adding known amounts of Simazine to a composite of the soil and permitting the samples so treated to stand for 3 and 5 days previous to analysis. A recovery of 80 per cent (with very little deviation) of added Simazine was quite consistently obtained from soil samples to which applications ranging from light to heavy had been made. The Recovery Correction Factor was thus 1.25; all results recorded in Table I have been corrected by the use of this factor.

Since rainfall and soil properties, such as texture and organic matter content, are quite important in determining the behaviour of Simazine in a soil, precipitation data were obtained from the Weather Station, the Physics Department, Ontario Agricultural College, and the more pertinent soil data from the Soils Department, Ontario Agricultural College.

*Geigy Agricultural Chemicals, Ardsley, N.Y. *Private communication.*

TABLE 1. — RESULTS OF CHEMICAL ANALYSES OF SOIL SAMPLES AFTER TREATMENT WITH 2-CHLORO-4,6-BIS (ETHYLAMINO)-S-TRIAZINE (SIMAZINE) ON MAY 24, 1958[1]

Rate of application (lb. active/acre)	Soil layer (inches)	Amount found in lb./acre			
		July 10/58	Aug. 28/58	May 25/59	May 27/60
0.5	0–1	0.11	0.07	0.02	
	1–2	0.07	0.04	0.02	
	2–4	0.12	0.10	0.00	
	4–6		0.03	0.00	
	6–8			0.00	
1	0–1	0.19	0.10	0.04	0.01
	1–2	0.10	0.06	0.01	0.01
	2–4	0.12	0.14	0.02	0.01
	4–6		0.05	0.00	Trace
	6–8			0.00	Trace
2	0–1	0.43	0.22	0.06	0.02
	1–2	0.18	0.07	0.01	0.01
	2–4	0.08	0.15	0.02	0.01
	4–6		0.04	Trace	Trace
	6–8			0.00	0.01
6	0–1	1.84	1.22	0.22	0.03
	1–2	0.42	0.21	0.06	0.02
	2–4	0.24	0.24	0.08	0.02
	4–6		0.06	0.02	Trace
	6–8			Trace	0.00
10	0–1	3.40	3.05	0.71	0.11
	1–2	0.63	0.34	0.14	0.05
	2–4	0.29	0.14	0.09	0.05
	4–6		0.06	0.03	0.01
	6–8			0.03	0.00
20	0–1	7.52	5.87	2.35	0.46
	1–2	1.03	0.80	0.27	0.20
	2–4	0.67	0.60	0.17	0.16
	4–6		0.21	0.06	0.05
	6–8			0.02	0.02

[1]Certain of the lower soil layers and the 0.5 lb./acre plots were not analysed at all of the sampling dates, since it was felt that the amount present would be insignificant. It should be noted that the last three soil layers each represent twice as great a volume as each of the first two.

EXPERIMENTAL RESULTS AND DISCUSSION

The results of the chemical analyses of the soil samples are given in Table 1. The recorded values represent the average of those of replicated plots. Agreement between the same soil layers of similarly treated plots was, in general, quite good. Soil data are given in Table 2 and precipitation data in Table 3. The climatic and soil data should facilitate comparison of our Simazine residue data with such data from other areas and should permit predictions as to the probable behaviour of Simazine under conditions somewhat similar to those of this study. There was very little evidence of lateral movement of Simazine in the soil.

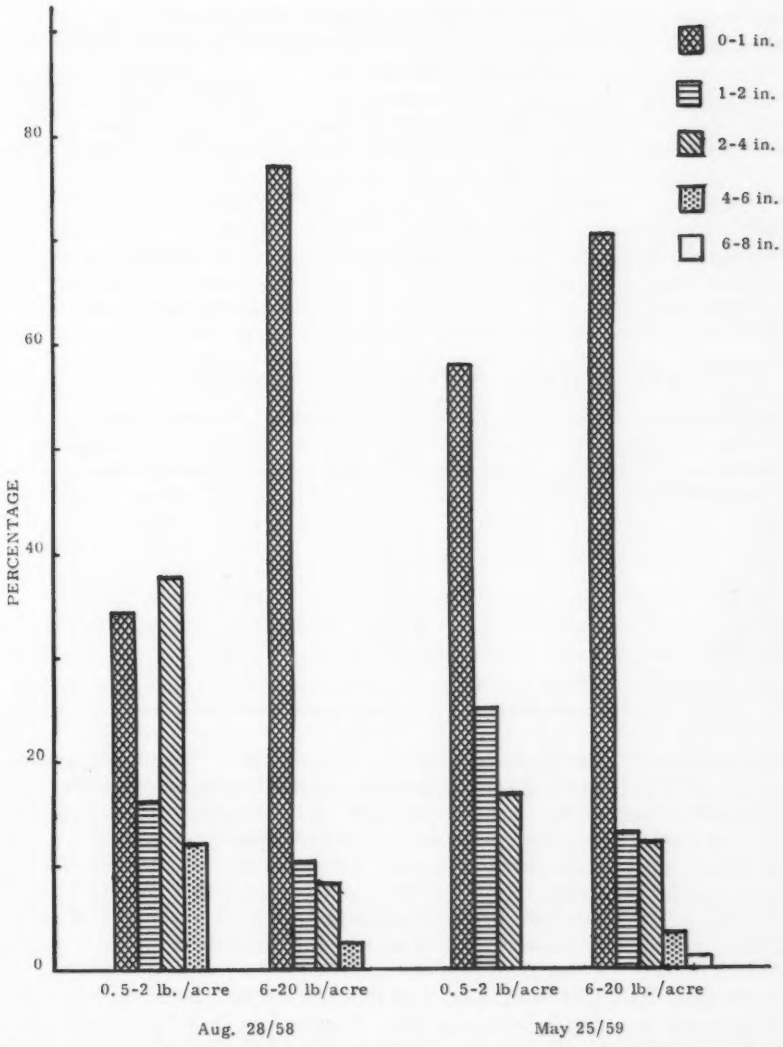

FIGURE 1. Average distribution of 2-chloro-4,6-bis(ethylamino)-s-triazine (Simazine) in the different sampling layers.

Rate and Extent of Soil Penetration of Simazine

Examination of Table 1 and Figure 1 will indicate that at the time of the final 1958 sampling (96 days after application) a much greater proportion of the residual Simazine was present in the lower layers in those plots receiving the lighter applications than in those plots receiving the heavier applications,

TABLE 2. — ANALYSES OF SOIL FROM THE PLOT AREA

Sample[1]	Mechanical analysis				Organic matter	Max. water holding capacity	Moisture equivalent
	Sand	Silt	Clay	pH			
	%	%	%		%	%	%
Range 1 (0-8 in.)	62	17	21	7.1	2.85	65.7	20.6
Range 2 (0-8 in.)	61	19	20	7.1	2.20	66.0	20.2

[1]These samples represent composites of the respective ranges

TABLE 3. — MONTHLY PRECIPITATION DURING EXPERIMENTAL PERIOD — INCHES OF RAINFALL

Month	1958	1959	1960
January to March[1] (inclusive)		7.38	7.15
April		2.90	2.50
May	1.45	2.49	5.77
June	1.74	1.19	3.23
July	3.74	3.53	
August	4.40	2.23	
September	5.24	2.77	
October	0.95	4.14	
November	3.80	3.28	
December[1]	1.94	3.52	

[1]Precipitation occurred as both snow and rain. All has been converted to, and is expressed as, rainfall.

where most was still concentrated in the 0-1 inch layer. Where the applications were 0.5, 1, and 2 lb./ac. the average distribution between the 0-1, 1-2, 2-4, and 4-6 inch layers was 34.5 per cent, 16.1 per cent, 37.7 per cent and 11.7 per cent, respectively; whereas, where the applications were 6, 10, and 20 lb./ac., the average distribution was 78.0 per cent, 10.7 per cent, 8.6 per cent, and 2.7 per cent. However, it should be noted that the amounts of Simazine in the lower layers actually increase somewhat as the rate of application is increased. Corresponding to the applications of 0.5, 1, 2, 6, 10, and 20 lb./ac., the total amounts of Simazine in the layers comprising 1-6 inches were 0.17, 0.25, 0.26, 0.51, 0.54 and 1.61 lb./ac. Since the solubility of Simazine in water is extremely low (5 p.p.m.), it is quite probable that its movement in the soil is more a function of rainfall than of concentration. It would appear that the rainfall during the period under consideration was insufficient to carry larger quantities of Simazine down to the lower soil layers. The total rainfall was 8.75 inches. The first month following the application of the Simazine was quite dry, but temperatures were relatively low, the highest maximum temperature recorded being 76°F. Later, however, there were several quite heavy rains, one of 0.95 inch on June 25, one of 1.38 inches on July 3 (with another 1 inch during the next 2 days) and a third of 1.29 inches on August 20.

On May 25, 1959, 1 year after application, the trend discussed in the first portion of the previous paragraph was much less marked. Where the applications were 0.5, 1, and 2 lb./ac., the average distribution between the 0-1, 1-2, 2-4, 4-6, and 6-8 inch layers now was 57.9 per cent, 25.1 per cent, 16.9 per cent, 0.0 per cent, and 0.0 per cent, respectively; the Simazine had disappeared almost entirely from the 4-6 and 6.8 inch layers. Where the applications were 6, 10, and 20 lb./ac. the average distribution was 70.3 per cent (81.9 in 20 lb./ac. plots), 13.1 per cent, 12.0 per cent, 3.4 per cent and 1.2 per cent. The total precipitation (expressed as rainfall) during the first year was 34.14 inches. While no doubt the increased precipitation, particularly during September, 1958, resulted in somewhat greater penetration of the Simazine, the full effect of this is not evident due to the marked disappearance of Simazine in the interval.

On May 27, 1960, 2 years after application, the greatest concentration of Simazine was still in the 0-1 inch layer. With the exclusion of the original 1 lb./ac. plot, the total of the combined amounts present in the second and third layers (i.e., 1-2 and 2-4 inches) will approximately equal the total of the amounts present in the 0-1 inch layers. In general, very little is present in the two lower layers. The total precipitation during the second year was 34.55 inches.

Persistence of Simazine in the Soil

Table 4 (which is based on the data of Table 1) indicates that on July 10, 1958, 47 days after application, an average of 44.4 per cent of the applied Simazine was still present, and that at the time of the final 1958 sampling 34.8 per cent was present. However, by the end of the first year the average percentage of applied Simazine present was only 8.4 per cent, the 0.5, 1, and 2 lb./ac. plots averaging 6.5 per cent and the 6, 10, and 20 lb./ac. plots averaging 10.2 per cent (20 lb./ac. plots 14.4 per cent). By the end of the second year the average percentage of applied Simazine present was only 2.7 per cent, with the 20 lb./ac. plots still containing the highest percentage of applied Simazine (4.4 per cent).

TABLE 4. — PERCENTAGE OF SIMAZINE ORIGINALLY APPLIED STILL REMAINING, 0-8 INCHES, AT VARIOUS SAMPLING DATES

Rate of application (lb. active/acre)	Sampling dates			
	July 10/58	Aug. 28/58	May 25/59	May 27/60
	%	%	%	%
0.5	60.0	48.0	8.0	
1	41.0	35.0	7.0	3.0
2	34.5	24.0	4.5	2.5
6	41.7	28.8	6.3	1.2
10	43.2	35.9	10.0	2.2
20	46.1	37.4	14.4	4.4
Average	44.4	34.8	8.4	2.7

Consideration of Table 4 further shows that the rate of loss of Simazine during the second year following application was somewhat less than during the first year. During the first year an average of 91.6 per cent of the applied Simazine disappeared, whereas during the second year approximately only 68 per cent of the Simazine present at the beginning of that year disappeared.

It is of interest to compare the disappearance of Simazine in this experiment with that of monuron (CMU) determined in a similar experiment (quite similar surface soil, comparable rainfall, etc.) conducted several years ago by Birk (2). The disappearance of monuron was proportionally considerably greater than that of Simazine during the summer season but during the fall and winter this condition was reversed. As pointed out in the monuron study, the late summer results tended to be somewhat low because the sampling period had been preceded by a period of very little rainfall, so that the surface soil was quite dried out, resulting in recoveries of monuron somewhat below normal. Hence a direct comparison of the results of the two studies is probably not justified; nevertheless, the above statement is still considered valid.

The disappearance of monuron under field conditions is generally considered to be due primarily to microbiological decomposition. On the other hand, while the work of Pochon (5) suggests that soil bacteria are probably not implicated in Simazine decomposition, the studies of Guillemat (4) and Eno* indicate that fungi are very probably involved in its breakdown.

If, as suggested, fungi are involved in the degradation of Simazine, conditions during September, 1958, should have been very favourable for this, since the rainfall was 5.24 inches and temperatures were also relatively high.

Weed Control and Growth of Indicator Crops

Since most of the plot area was heavily infested with redroot pigweed and couch grass previous to the beginning of the experiment, observations have been made on the control of these weeds. In general, as illustrated in Table 5, over a period of three growing seasons, the growth of redroot pigweed has correlated relatively well with the total Simazine content of the plots as determined by analysis. Quite good control was obtained with a total Simazine content of 1 lb./ac. or above, but below this value control dropped off fairly rapidly. The original 20 lb./ac. plots which by June, 1960, contained only about 0.89 lb./ac., still showed fairly good control, but a few pigweed plants were making their appearance.

In 1958 it was noted that the 6 lb. active/ac. application of Simazine gave appreciable control of couch grass and that the 10 lb./ac. application gave practically complete control. Since, in the Guelph area at least, 10 lb./ac. of Simazine has been shown to cause no injury to numerous varieties and inbred lines of corn, this suggests the use of this herbicide in the cleaning up of certain hard-to-control perennial weeds, such as couch grass, while continuing to grow corn.

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*Eno, C. F. Agricultural Experiment Stations, University of Florida. *Personal communication.*

TABLE 5. — CONTROL OF REDROOT PIGWEED

Simazine application (lb. active/acre, 1958)	Total residue (lb./acre)	Control
1	—	Quite good in 1958
	0.07 (May/59)	None in 1959
6	—	Complete in 1958
	0.38 (May/59)	None in 1959
10	—	Complete in 1958
	1.0 (May/59)	Quite good in 1959
	0.22 (May/60)	None in 1960
20	—	Complete in 1958
	2.87 (May/59)	Complete in 1959
	0.89 (May/60)	Fairly good in 1960

During the fall of 1959 several drills of fall wheat were sown across all of the plots. Examination in the spring of 1960 indicated no damage due to Simazine on any of the plots except the 10 lb./ac. and the 20 lb./ac. plots. Some damage was evident on the 10 lb./ac. plots but there was considerable survival of the plants. On the 20 lb./ac. plots there was considerable damage with only a small amount of survival. During the latter part of June, 1960, the plot area was ploughed and a seed bed prepared and sown to oats. Examination the end of July showed a poor stand of oats on the 20 lb./ac. plots, a very considerable proportion of the plants having been killed. On the 10 lb./ac. plots there was a small amount of injury, but there was no evidence of damage on any of the other plots. The fact that oats are more susceptible to Simazine than redroot pigweed was clearly illustrated in the 20 lb./ac. plots where pigweed was growing quite well in areas where most of the oats had been killed.

CONCLUSIONS

The chemical analytical data relating to the penetration and persistence of Simazine resulting from this study should prove to be a very useful supplement to the considerable data available from experiments employing plant indicator methods. The data obtained indicate that amount of rainfall is an important factor in determining the extent of penetration of this relatively insoluble herbicide. With a minimum of rainfall a considerably smaller proportion of the residual Simazine was present in the lower soil layers in those plots receiving the heavier applications than in those plots receiving the lighter applications, although the former plots did show somewhat larger total amounts in the lower layers than the latter. However, even after 2 years the greater proportion of the residual Simazine was still in the 0-1 inch layer; in general, the total of the combined amounts present in the layers comprising 1-6 inches was approximately equal to the amounts present in the 0-1 inch layers.

Concerning persistence, 1 year after application an average of only 8.3 per cent of the Simazine originally applied still remained and by the end

of 2 years this value had dropped to an average of only 2.7 per cent, with the plots which had received the heaviest application (20 lb./ac.) showing the highest percentage of residue; however, even in these plots there now remained only 0.89 lb./ac., an amount which would control certain weeds, such as redroot pigweed, fairly satisfactorily for another season but would be ineffective in controlling various other weeds, although still proving quite toxic to highly susceptible crops such as oats.

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STUDIES WITH FERTILIZED PASTURES ON A HEAVY TEXTURED SOIL IN NORTHERN ALBERTA

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ABSTRACT

Yields of herbage, animal gains, carrying capacity and TDN production were determined for three pasture swards grown on a Grey Wooded soil (Albright-Hythe series) in the Peace River region of northern Alberta over the period 1953 to 1956 inclusive. Sheep were used as grazing units. Fertilizer treatments of nil, ammonium phosphate (11-48-0) at 300 pounds per acre and ammonium nitrate (33-0-0) at 100 pounds per acre were applied annually to pastures of creeping red fescue, creeping red fescue-alfalfa and bromegrass-alfalfa.

Productivity obtained with unfertilized grass-legume mixtures was almost double that for unfertilized grass grown alone. Increased production attributable to alfalfa was also obtained, although to a lesser degree, where fertilizers were used. Pastures of creeping red fescue seeded alone and with alfalfa responded markedly to applications of nitrogen while responses to phosphorus were negligible. Conversely, bromegrass-alfalfa pastures responded strongly to applications of phosphorus and only slightly to nitrogen.

INTRODUCTION

It is estimated that over 80 per cent of the potentially arable land in the Upper Peace River region is comprised of Grey Wooded and Degraded Black soils; hence future settlement will be principally on these soils (1). The importance of grasses and legumes in the farm program to maintain and, where possible, improve fertility has long been heralded (2). However, their production potential under a pasture program involving cultivated species and fertilization has not been determined. This paper deals with a comparison of creeping red fescue grown alone and in association with alfalfa, and a bromegrass-alfalfa mixture, and the response of these to applications of nitrogen and phosphorus.

MATERIALS AND METHODS

The experiment was located approximately 25 miles northwest of the Beaverlodge Experimental Farm. The soil is of the Albright and Hythe series and is representative of the Hythe-Goodfare-Brainard district. It is characterized by a shallow A_0A_1 horizon and a heavy-textured and relatively impermeable subsoil (5). The structure is readily destroyed and the fertility quickly depleted under continuous cropping and cultivation. Erosion, a formidable factor in the region, is accelerated under such conditions. The particular field chosen for this study had been continuously cropped and cultivated on an annual basis for 25 years.

Three pasture swards were involved as main plots and two fertilizers and a check as the sub-plots in a split plot design with three replicates. A fourth replicate was maintained as a spare pasture.

Each main sward was 3 acres in area, subdivided into three sub-pastures of 1 acre each. Sub-pastures were cross-fenced, making two pastures which were grazed rotationally.

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The experimental area was fallowed in 1951 and seeded without a cereal companion crop in the spring of 1952 to the following:

Sward I – creeping red fescue	variety Olds	@ 10 lb. per acre
Sward II – creeping red fescue	variety Olds	@ 7 lb. per acre
+ alfalfa	variety Rhizoma	@ 5 lb. per acre
Sward III – bromegrass	variety Local Commercial	@ 15 lb. per acre
+ alfalfa	variety Rhizoma	@ 5 lb. per acre.

The following fertilizers were applied as a top dressing at time of seeding and in the early spring of each following year throughout the study:

Sub. 1 – No treatment	
Sub. 2 – Ammonium phosphate (11-48-0)	@ 300 lb. per acre
Sub. 3 – Ammonium nitrate (33-0-0)	@ 100 lb. per acre.

The productivity of each pasture was measured by herbage yields, animal gains, carrying capacity, and total digestible nutrients (TDN). Supplementary data were obtained on botanical composition and chemical analyses of the herbage.

Yield of pasture herbage was measured by the "Difference Method" (4) and reported in pounds dry matter per acre. Equal portions of both caged and grazed areas were clipped each time the sheep were moved in the rotation grazing program, which was approximately every 2 weeks.

Sheep of predominantly Hampshire breeding were used as grazing animals and were allotted to the pastures on the basis of two ewes, one with a single lamb and one with twins, per acre. Extra animals, which were kept on the spare pasture, were allotted to those pastures requiring heavier grazing. Occasionally pastures had to be given a recovery period with all animals removed. Animal gains were calculated by obtaining animal weights on 2 consecutive days prior to placing the animals on test and approximately every 2 weeks throughout the season as they were moved in the rotation.

The carrying capacity was determined by recording the number of days each animal grazed on each pasture. These data were converted to animal unit pasture days on the basis of seven ewes or fourteen lambs being equal to one mature steer (7). TDN production was calculated according to the procedure outlined by Sylvestre and Williams (6). The point sampler, containing 36 points, 1 inch apart, was employed in determining winter killing and changes in pasture composition (3). Chemical composition of herbage was determined on a dry matter basis from a representative 500-gram sample taken from each sub-plot. Samples were collected in the early summer from the regrowth when it attained a height of approximately 6 inches following the first grazing.

EXPERIMENTAL RESULTS

Average yield data for the period 1953-56 for each measure of pasture productivity are presented in Table 1.

Herbage Yields

When the different treatments on the same pasture are considered, both fertilizer treatments outyielded the nil treatment when applied to creeping red fescue seeded alone and with alfalfa. With the bromegrass-alfalfa pasture the 11-48-0 treatment produced more than did either the nil or the 33-0-0 treatment.

TABLE 1. — AVERAGE PRODUCTIVITY OF FERTILIZED PASTURES, 1953-56

Treatments	Herbage yields in pounds dry matter per acre	Animal gains in pounds lamb per acre	Carrying capacity in animal unit pasture days per acre	Total digestible nutrients in pounds per acre
		Main Effects		
Pastures				
Creeping red fescue	2172	134.5	53.9	927
Fescue+alfalfa	3326	195.4	75.8	1402
Bromegrass+alfalfa	3172	202.7	63.3	1252
L.S.D. .05	645	15.9	9.8	142
Fertilizers				
Nil	1970	137.4	47.7	900
11-48-0	3672	219.4	79.0	1460
33-0-0	3029	175.7	66.3	1220
L.S.D. .05	210	12.9	5.2	72
		Interactions		
Creeping Red Fescue				
Nil	1062	86.5	33.8	568
11-48-0	2821	165.7	66.8	1142
33-0-0	2634	151.2	61.0	1070
Fescue+alfalfa				
Nil	2289	160.8	57.2	1104
11-48-0	4002	219.5	89.5	1625
33-0-0	3688	205.8	80.8	1476
Bromegrass+alfalfa				
Nil	2558	165.0	52.0	1028
11-48-0	4192	273.0	80.8	1614
33-0-0	2765	170.2	57.2	1114
L.S.D. .05				
Two fertilizers on same pasture	467	24.3	12.1	144
Same fertilizer on different pastures	706	24.0	10.2	174

Both mixtures outyielded fescue alone when both the nil and the 11-48-0 treatments are considered. However, when 33-0-0 was applied, herbage yields from the fescue-alfalfa pastures were higher than the yields from the other two pastures.

Animal Gains

On pastures grazed at an optimum rate, the ewes maintained their weight, while the lambs gained at approximately three-quarters of a pound per day. On undergrazed pastures, where the basic unit of two ewes and three lambs were not able to graze down the allotted area in 2 weeks, it was noted that ewes readily gained weight. When this situation arose, additional animals were provided. In over-grazed pastures, ewes often lost weight. The net gain or loss of weight of ewes was negligible and not considered in animal weight gains.

Differences in animal gains were obtained with both fertilizer treatments on the fescue and the fescue-alfalfa pastures, with no difference occurring between fertilizers. However, when applied to the bromegrass-alfalfa pasture, the 11-48-0 treatment outyielded both the nil and the 33-0-0 treatment by a very wide margin.

Among the unfertilized pastures the grass-legume mixtures produced more pounds of lamb than fescue alone with no difference between mixtures. Considering only the 11-48-0 treatment, both mixtures were again superior to fescue but the response from the bromegrass-alfalfa pasture surpassed that from the fescue-alfalfa pasture. Where 33-0-0 was applied the greatest response was noted in the fescue-alfalfa pastures which outyielded the other two pastures. For this treatment the differences between bromegrass-alfalfa and pure fescue were not significant.

Carrying Capacity

Both fescue and fescue-alfalfa pastures showed equal responses to applications of 33-0-0 and 11-48-0. The bromegrass-alfalfa pasture, however, responded only to the 11-48-0 treatment.

Both mixtures proved superior to the pure grass pasture when no fertilizer was applied and when 11-48-0 was applied. The 33-0-0 treatment increased the carrying capacity only on the fescue-alfalfa.

Total Digestible Nutrients

Both fertilizers outyielded the check when applied to the fescue and the fescue-alfalfa pastures, while the latter pasture responded more strongly to 11-48-0 than to 33-0-0. Bromegrass-alfalfa also responded only to the 11-48-0 treatment.

Fescue-alfalfa and bromegrass-alfalfa were similar and superior to the pure grass pasture when treated with 11-48-0 or when left untreated. However, the response of fescue-alfalfa to the 33-0-0 treatment was again reflected with yields significantly higher than those produced from the pure fescue or the bromegrass-alfalfa pastures.

Plant Count Data

The increase in the creeping red fescue count where fertilizers were applied was significant ($P = <.01$) both in the pure stand and the fescue-alfalfa pasture (Table 2). However, in neither case was there a significant difference between fertilizers, indicating that the response was attributable only to the addition of nitrogen.

The bromegrass population (Table 2) was increased significantly only by 11-48-0. This suggests that the nitrogen requirements of bromegrass were satisfied by the legume associate and that phosphorus alone promoted the increase.

The wide difference between the alfalfa populations in the two mixtures indicates the greater competitive feature of creeping red fescue. In the creeping red fescue association the alfalfa population decreased as the grass population increased. This reduction was significant where nitrogen was applied. The slight reduction of alfalfa in the 11-48-0 pastures was not

TABLE 2. — PLANT COUNT DATA FOR THREE PASTURE SWARDS, AUTUMN COUNT — 1956

Species	Pasture	Fertilizer	Count	Differences between check and fertilizer	Differences between fertilizers
Fescue	Fescue	Nil	509	—	—
		11-48-0	781	272**	—
		33-0-0	720	211**	61
Fescue	Fescue+ alfalfa	Nil	633	—	—
		11-48-0	748	115**	—
		33-0-0	733	100**	15
Bromegrass	Brome+ alfalfa	Nil	317	—	—
		11-48-0	384	67*	—
		33-0-0	304	−13	80**
Alfalfa	Fescue+ alfalfa	Nil	96	—	—
		11-48-0	72	−24	—
		33-0-0	50	−46**	22*
Alfalfa	Brome+ alfalfa	Nil	144	—	—
		11-48-0	117	−27	—
		33-0-0	130	−14	13

*Differences significant at the 5% level
**Differences significant at the 1% level

significant and suggests that alfalfa produced a stronger stand where phosphorus was applied. In the bromegrass mixture the alfalfa population was not significantly influenced by fertilizing.

Chemical Composition of Pasture Herbage

The chemical composition of the herbage as determined for the various pastures, fertilizer treatments and pastures x fertilizer interactions are presented in Table 3. Since yearly variations were negligible, 3-year average data are presented.

The percentage of protein varied markedly with treatments. Comparing unfertilized pastures both mixtures yielded significantly more protein than creeping red fescue alone, while bromegrass-alfalfa proved superior to fescue-alfalfa. For creeping red fescue alone and bromegrass-alfalfa protein was increased by both fertilizers indicating that the phosphorus in the ammonium phosphate had little or no effect on this component. The protein content of fescue-alfalfa pasture, however, failed to respond to either of the fertilizer treatments.

The only significant variation in the percentage of fibre was in the fertilizer main effect where a reduction in fibre resulted from fertilizing.

A variation in the content of mineral matter was found only as an interaction effect when comparing two levels of fertility on the same pasture. Both fertilizers reduced the mineral matter content of the pure fescue pasture, while only the ammonium nitrate caused a reduction in the bromegrass-alfalfa pasture. Variations in the fescue-alfalfa mixture were not significant.

The calcium component varied with pastures but not with fertilizers in the main effects. The variation in pastures is attributed to the legume component since both mixtures showed significantly more calcium than the pure grass sward. This variation is reflected again in the interaction comparison.

TABLE 3. — AVERAGE CHEMICAL COMPOSITION IN PER CENT BASIS DRY MATTER OF HERBAGE FROM FERTILIZED PASTURES, 1953, 1955 AND 1956

Treatments	Protein	Fat	Fibre	Nitrogen-free extract	Mineral matter	Calcium	Phosphorus
				Main Effects			
Pastures							
Creeping red fescue	9.05	1.88	30.28	50.69	8.10	0.40	0.23
Fescue+alfalfa	11.63	1.74	29.10	49.59	7.90	0.69	0.23
Bromegrass+alfalfa	15.13	2.10	30.68	48.25	8.19	0.80	0.23
L.S.D. .05	1.64	NS	NS	NS	NS	0.16	NS
Fertilizers							
Nil	11.15	1.95	33.04	49.73	8.47	0.71	0.18
11-48-0	12.27	1.98	28.31	49.43	7.97	0.56	0.31
33-0-0	12.39	1.80	28.70	49.37	7.75	0.62	0.20
L.S.D. .05	1.06	NS	1.98	NS	NS	NS	0.09
				Interactions			
Creeping Red Fescue							
Nil	7.76	2.04	31.22	50.09	8.89	0.39	0.20
11-48-0	9.76	1.86	29.66	51.11	7.67	0.38	0.30
33-0-0	9.62	1.74	29.95	50.88	7.75	0.43	0.19
Fescue+alfalfa							
Nil	11.50	1.78	28.77	49.85	8.09	0.84	0.20
11-48-0	11.70	1.75	29.45	49.13	7.82	0.60	0.30
33-0-0	11.70	1.70	29.08	49.78	7.80	0.64	0.20
Bromegrass+alfalfa							
Nil	14.20	2.02	39.13	49.26	8.43	0.91	0.14
11-48-0	15.36	2.33	25.84	48.06	8.42	0.70	0.34
33-0-0	15.84	1.95	27.08	47.44	7.71	0.80	0.20
L.S.D. .05							
Two fertilizers on same pasture	1.14	NS	NS	NS	0.36	NS	0.08
One fertilizer on different pastures	1.41	NS	NS	NS	NS	0.09	NS

Variations in the percentage of phosphorus in pasture herbage were attributed to applications of supplemental phosphorus as supplied by the ammonium phosphate. The greatest increase occurred in the bromegrass-alfalfa mixture where the application of ammonium phosphate increased the phosphorus content from 0.14 to 0.34 per cent.

DISCUSSION AND CONCLUSIONS

For this study productive cultivated pastures were readily established on a depleted heavy-textured soil frequently encountered in the Upper Peace River region. The superiority of the grass-legume mixtures to the grass grown singly for pasture was clearly shown. Herbage yield, animal gains, carrying capacity and TDN production measured significant increases for both mixtures over creeping red fescue by itself. Fescue-alfalfa excelled in TDN production and in carrying capacity.

Both fertilizers produced significant increases over the nil treatment but the increases resulted from different components. The response of creeping red fescue, seeded alone and with alfalfa, to applications of nitrogen was significant for each of the measurements of productivity, while the

response to phosphorus was negligible. On the other hand, bromegrass showed no requirement for nitrogen over the amounts supplied by the alfalfa since applications of ammonium nitrate failed to produce a measurable response. However, the need for phosphorus was demonstrated with bromegrass by significant increases for all production measures when phosphorus was added. Alfalfa, seeded at the same rate in both pasture mixtures, was apparently unaffected directly by fertilizing but suffered indirectly where the competitive nature of the grass was enhanced by added fertility. The apparent difference in the response of the two grasses on trial to nitrogen and phosphorus was also reflected in the plant count data.

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CORM TREATMENTS FOR THE CONTROL OF CURVULARIA CORM ROT OF GLADIOLUS IN CANADA[1]

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ABSTRACT

Eight fungicidal preparations were tested as pre-planting corm treatments for the control of Curvularia rot of gladiolus corms in artificially infested field plots at Ottawa in 1957 and 1958. The thiram preparations Delsan A-D, Arasan SF-M, and Arasan SF-X applied as dusts gave the best control of the disease. These dusts significantly decreased the percentage of plants affected with Curvularia corm rot during both seasons. They also significantly increased stand, total corm yield, and number of rot-free corms harvested in 1957 but these benefits could not be shown statistically in 1958. Arasan SF-M and Arasan SF-X delayed flowering 4-5 days in both years and Delsan A-D delayed emergence 6 days and flowering 5 days in 1957. Arasan used as a dust and Dowicide B, Emmi, mercuric chloride, and Ortho Seed Guard Wettable used as soaks did not give satisfactory control of the corm rot.

INTRODUCTION

In the United States, the Curvularia disease of gladiolus, caused by *Curvularia trifolii* (Kauffm.) Boed. f. sp. *gladioli* Parmelee and Luttrell (3), is destructive to the flowers and leaves as well as the corms (2). In Ontario and Quebec, the disease occurs primarily as a corm rot. Since the pathogen is soil- and corm-borne it might be expected that the disease could be controlled by treating the corms with a fungicide before planting. Tests to determine the effectiveness, in Canada, of commercial fungicides as pre-planting corm treatments were made at Ottawa in 1957 and 1958.

MATERIALS AND METHODS

Each treatment was applied to 100 healthy, peeled, size 4 corms of the variety Spic and Span just before planting. The chemicals used and the methods of application were as follows:

Arasan [50% thiram (tetramethylthiuramdisulfide)], dust
Arasan SF-M (75% thiram plus 2% methoxychlor)[3], dust
Arasan SF-X (75% thiram)[3], dust
Delsan A-D Seed Protectant [60% thiram plus 15% dieldrin (hexachloroepoxyoctahydro-endo, exo-dimethanonaphthalene)][3], dust
Dowicide B (85% sodium trichlorophenate)[4], 6 pounds per 40 imperial gallons, 30-minute soak
Emmi (10.34% N-ethylmercuri-1,2,3,6-tetrahydro-3,6-endomethano-3,4,5,6,7, 7-hexachlorophthalimide)[5], 1 pint per 40 imperial gallons, 2-hour soak. In 1958 a 1-hour and a 15-minute soak were also tested.
Mercuric chloride, 1:1000, 3-hour soak
Ortho Seed Guard Wettable [50% captan (N-trichloromethylmercapto-4-cyclohexene-1, 2-dicarboximide) plus 16.5% gamma isomer of benzene hexachloride from lindane][6], 1 pound per 40 imperial gallons, 30-minute soak. As this chemical settled slowly the solution required occasional stirring.

Corms to be treated with a dust were shaken in a paper bag containing a sufficient amount of the material to ensure good coverage. In preliminary trials with all of the dusts, 1 teaspoonful usually gave satisfactory coverage

[1]Contribution No. 100 from the Plant Research Institute, Research Branch, Canada Department of Agriculture, Central Experimental Farm, Ottawa, Ont.
[2]Plant Pathologist.
[3]Supplied by E. I. DuPont de Nemours and Co.
[4]Supplied by Dow Chemical of Canada, Ltd.
[5]Supplied by Velsicol Chemical Corp.
[6]Supplied by Ortho Agricultural Chemicals Ltd.

of the corms. However, large amounts of Delsan A-D, Arasan SF-M, and Arasan SF-X clung to the sides of the bag and to assure good coverage 2 teaspoonfuls of these dusts were required. Therefore, in all of the dust treatments, 2 teaspoonfuls were used.

Preparatory to planting, trenches were dug in sandy loam soil in a field plot. The soil in the bottom of the trenches was artificially infested by mixing with it, at the rate of 70 grams per foot, 1 month-old cultures of the pathogen grown on sterilized wheat grains. Immediately after treatment, the corms were placed in the trenches and surrounded by the infested soil. The corms were planted in randomized blocks with four replications of 25 corms for each treatment. Planting was done on May 24 and May 27 in 1957 and on May 26 and May 27 in 1958.

To evaluate the effects of the treatments on the disease and plant development, records were kept on the date of emergence, the number of plants that emerged, the date the first florets opened, the length of the flower head, the percentage of plants that became affected with Curvularia corm rot during the season, and the number of rot-free corms harvested in October, as well as of the total corm yield. Corm decay during the season, as indicated by yellowing of the plant leaves, was attributed to *Curvularia* only if the pathogen was found sporulating on the corm lesions or if it could be isolated from the affected tissues.

RESULTS AND DISCUSSION

The results obtained from tests with eight chemicals in 1957 and 1958 are shown in Table 1. The data for the length of the flower head are not included in the table because differences between the treatments could not be shown statistically.

Some treatments significantly delayed emergence in 1957 but not in 1958 when the time from planting to emergence was longer because of lower soil temperature. From the time of planting to the end of May the average soil temperature at the 4-inch depth under sod was 59.2°F. in 1957 compared with 55.5°F. in 1958. The average soil temperatures for June in the same years were 67.6°F. and 62.1°F., respectively (4). The soil temperatures for July-October inclusive differed only slightly between the 2 years.

In 1957, several treatments significantly increased the stand but such increases were not obtained with any of the treatments in the following year. In 1958, the lower soil temperature in May and June may have slowed disease development because a good stand was obtained in the untreated check with the result that none of the treatments showed an apparent increase in emergence.

In both years there was good development of the corm rot during the season but when the corms were harvested a smaller percentage in the check was affected with Curvularia rot in 1958 than in the previous year. For this reason none of the treatments in 1958 significantly increased the yield of rot-free corms although increases were obtained with some treatments in 1957.

TABLE 1.—THE EFFECTS OF PRE-PLANTING TREATMENTS OF GLADIOLUS CORMS FOR THE CONTROL OF CURVULARIA CORM ROT

Treatment	Average number of days from planting to emergence	Emergence from 100 corms	Average number of days from planting to flowering	Per cent of plants affected with corm decay during the season	Number of corms harvested	Number of rot-free corms
1957						
Arasan	32**	95*	118**	2.1	87**	58
Arasan SF-M	28	99**	116**	0.0**	95**	74**
Arasan SF-X	27	100**	116**	0.0**	95**	76**
Delsan A-D	30*	95*	117**	0.0**	93**	70**
Dowicide B	28	96**	117**	12.5	82**	55
Emmi 2-hr. soak	37**	44**	117**	4.5	42*	31
Mercuric chloride	25	92	114	13.0*	74*	42
Ortho Seed Guard Wettable	26	94*	113	5.2	93**	69**
Untreated check	24	82	112	6.1	59	40
1958						
Arasan	33	98	119	3.1*	92	74
Arasan SF-M	37	95	121**	2.0*	87	78
Arasan SF-X	35	98	122**	1.0**	95	83
Delsan A-D	38	96	119	1.0**	93	75
Dowicide B	36	96	120*	24.0	67	56
Emmi 2-hr. soak	—	0	—	—	—	—
1-hr. soak	53	4**	—	—	5**	5**
15-min. soak	36	97	123**	2.1*	93	75
Mercuric chloride	35	92	122**	16.3	75	62
Ortho Seed Guard Wettable	32	99	119	7.1	88	69
Untreated check	31	96	117	14.6	79	68

*Difference between the treatment and the untreated check significant at the 5% level
**Difference between the treatment and the untreated check significant at the 1% level

Dust treatments with Delsan A-D, Arasan SF-M, and Arasan SF-X resulted in significant decreases in the percentage of plants with corms decayed by *Curvularia* during the season in both years. These three treatments and also Ortho Seed Guard Wettable significantly increased the stand, the number of rot-free corms harvested, and the total yield of corms in 1957, but not in 1958. Arasan SF-M and Arasan SF-X delayed flowering 4-5 days in both years, and Delsan A-D delayed emergence 6 days and flowering 5 days in 1957. Ortho Seed Guard Wettable did not retard emergence or flowering at any time.

Dusting the corms with Arasan significantly reduced the percentage of plants affected with corm rot during the season in 1958, but not in 1957. This treatment did not increase the number of rot-free corms harvested in either year and it also retarded emergence and flowering in 1957. Arasan had a lower concentration of thiram and poorer sticking qualities than the other thiram preparations. Both of these factors probably contributed to the failure of Arasan in controlling the disease.

Neither Dowicide B nor mercuric chloride reduced Curvularia corm rot of the plants during the season, nor did these treatments increase the

number of rot-free corms harvested. Flowering was delayed by Dowicide B in both years and by mercuric chloride in 1957.

Emmi severely reduced emergence when it was used as either a 1- or 2-hour soak. However, when used as a 15-minute soak it reduced the number of plants affected with the corm decay during the season without delaying or reducing emergence. Flowering was delayed 6 days. This treatment requires further testing before it can be recommended as a control.

The results obtained from these tests indicate that the thiram preparations Delsan A-D, Arasan SF-M, and Arasan SF-X were the most effective of the chemicals tested as pre-planting corm treatments for the control of Curvularia corm rot in Canada. The insecticidal ingredients in Delsan A-D and Arasan SF-M had no apparent effect in controlling the disease because Arasan SF-X with only thiram as the active ingredient gave equally good control. In Illinois, Delsan A-D, Arasan SF-M, Dowicide B, and Emmi (2-hour soak) used the same as in these tests were effective in controlling the disease (1). However, at Ottawa, neither Emmi, used as 1- or 2-hour soak, nor Dowicide B gave satisfactory results.

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INFLUENCE OF POTASSIUM SPRAYS ON FOLIAR NECROSIS AND YIELDS OF ROMAINE LETTUCE, RADISHES, AND POTATOES[1]

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ABSTRACT

Spraying romaine lettuce with either muriate or sulphate of potash eliminated leaf scorch (leaf breakdown) in six trials and significantly increased the yield of one. In one experiment radishes showed no foliage symptoms, but those sprayed with muriate of potash gave significantly higher yield. Leaf necrosis of Green Mountain potatoes was reduced markedly by potassium sprays in each of 4 years, while yields of U.S. No. 1 tubers were greatly increased in 3 years. Differences between muriate and sulphate of potash were not significant at the concentration used. Potassium sprays during the growing season may be profitable on crops grown in soils deficient in potassium.

INTRODUCTION

During a period of almost continuous sunlight in 1955 romaine lettuce vigorously growing in the greenhouse developed leaf necrosis. Beginning at the tip, entire sections of leaves lost their turgidity and dried. The dried leaves retained their green colour several days but eventually bleached out.

At this time in many places in Alaska potato leaflets developed necrotic spots. In very early stages an affected field exhibited an over-all abnormally dark green colour. A few light green spots the size of a pin-head appeared between the veins of the larger leaflets. Leaf margins rolled upward from the middle to the top of the plant. Sometimes these small spots enlarged and combined with others. These early stages resembled the symptoms later reported on White Rose potatoes grown in California at a low potassium level (4). In some fields practically all the leaves on the plant rolled and became crisp and brown. Very high potassium fertilizer levels seemed to decrease lettuce leaf necrosis in the greenhouse and also potato leaf necrosis in the field. The present paper reports experiments on the effects of potassium foliage sprays on these disorders.

METHODS

A series of greenhouse experiments was conducted in 1956 and 1957 using Homestead silt loam with an original reaction of pH 5.7. Limestone flour was mixed with the entire lot of soil at the rate of 4 tons per acre. Three crops of lettuce in 1956 and one of radish in 1957 were grown successively in this lot of soil. Prior to each crop 119 and 300 pounds per acre of N and P_2O_5 were added as diammonium phosphate (21-53-0) in solution. Romaine lettuce and Crimson Giant Globe radish were planted in 6-inch plastic pots containing 1,000 grams of soil.

In two preliminary experiments in 1956 lettuce plants were dipped twice a week in muriate of potash solutions containing 0.63 per cent K_2O and a small amount of detergent. Because of the difficulty of retaining the soil while inverting the pots, the potassium solution at the same con-

[1]Journal paper, Alaska Agricultural Experiment Station, Palmer, Alaska.
[2]Soil Scientist.

centration was applied as a foliage spray to one lettuce crop in 1956 and one radish crop in 1957. Untreated plants were used as controls. Before harvest each lettuce plant was visually placed into one of four classes, depending upon the degree of leaf necrosis.

To determine if the 1956 response to K sprays resulted from the detergent, minor elements present in the muriate of potash, or K or Cl ions, three greenhouse lettuce crops were grown in a block lay-out of eight treatments replicated six times using a different lot of Homestead silt loam. Untreated plants were compared with plants sprayed with water containing only detergent, muriate of potash (fertilizer and analytical grade) with and without detergent, and analytical grade sulphate of potash with and without detergent.

The potato experiments were conducted on Bodenburg silt loam. Green Mountain potatoes were planted in 1956 in a well-managed field south of Palmer in the Matanuska Valley. In the preceding year this field had produced low potato yields. At planting time 60, 180, and 60 pounds of N, P_2O_5 and K_2O per acre respectively were banded in the row as 8-24-8 commercial fertilizer. Eight 25-foot sections of row were chosen at random in this field for foliar sprays. Beginning July 6, when the plants were 4 inches high, these plots were sprayed twice a week with muriate of potash solution containing 0.63 per cent K_2O and a small quantity of detergent thoroughly wetting the foliage. Eighteen sprays, equivalent to 12 pounds of K_2O per acre, were applied to these plots throughout the growing season. In the lettuce trials each plant was placed visually in one of four classes, according to severity of leaf necrosis, whereas in the potato experiments, the incidence of scorch was measured by the number of affected plants per 20-foot row. Yield records were also taken.

This work was repeated in a more formal experiment with the same potato variety in an adjacent field in 1957. These plots were fertilized with 11-48-0 applying 60 and 262 pounds of N and P_2O_5 per acre, respectively. Starting June 30, twenty sprays were applied.

TABLE 1. — RELATION OF MURIATE OF POTASH SPRAYS TO DEGREE OF LEAF DYING[1] OF LETTUCE AND YIELD OF LETTUCE AND RADISHES, 1956
(MEANS OF 24 MEASUREMENTS)

	Lettuce crop						Radish total green weight
	1		2		3		
	Degree of leaf dying	Dry matter	Degree of leaf dying	Dry matter	Degree of leaf dying	Dry matter	
		grams		grams		grams	grams
No spray	0.6	2.15	0.9	1.77	1.4	0.49	18.0
KCl spray	0.0	2.30	0.0	1.80	0.0	0.62	21.4
LSD 5%	0.3	N.S.	0.3	N.S.	0.15	N.S.	2.9
1%	0.4		0.4		0.20		3.9

[1] 0 None; 1 slight; 2 severe; 3 very severe

A "no spray" treatment was compared in 1958 and 1959 with both muriate and sulphate of potash sprays. The 1958 trials located 3 miles north of Palmer received twenty sprays and an over-all fertilization of 11-48-0 supplying 67 and 293 pounds per acre of N and P_2O_5 respectively. In 1959 the plots were on Alaska Experiment Station property adjacent to Palmer and received twenty-two sprays with 110 and 480 pounds of N and P_2O_5 per acre as 11-48-0.

RESULTS AND DISCUSSION

Lettuce and Radishes

Muriate of potash applied twice weekly either as a dip or a spray, completely eliminated lettuce leaf breakdown (Table 1). With each cropping of this Homestead silt loam the amount of lettuce leaf breakdown increased on the plants receiving no KCl sprays. Although the dry matter yields of sprayed lettuce plants always exceeded that of plants not sprayed, these differences were not significant statistically. Muriate of potash sprays significantly increased the yield of radish although no leaf scorching was observed in either the controls or treated plants.

Also in 1957 leaf scorch did not appear in any of the plants receiving sprays of potash in any of the forms tried. The decrease in breakdown between "no spray" and spray with water containing only a small quantity of detergent resulted from contamination with potassium which was detected after two sprayings. Potassium sprays also increased yields of all three 1957 lettuce crops. The increase with the first two crops was not large enough to be significant statistically. With the third crop this increase was significant. This lack of significant increase in the first two crops together with the progressive decrease in yield of each crop indicates the plants as a whole were starved for potassium, but the sprayed foliage received enough to prevent scorch. Sulphate of potash spray tended to

TABLE 2. — DEGREE OF LEAF DYING[1] AND YIELD OF LETTUCE AS RELATED TO FOLIAR SPRAYS OF DETERGENT, AND MURIATE AND SULPHATE OF POTASH WITH AND WITHOUT DETERGENT, 1957 (MEANS OF 6 MEASUREMENTS)

	Crop 1		Crop 2		Crop 3
	Degree of leaf dying	Dry matter	Degree of leaf dying	Dry matter	Dry matter
		grams		grams	grams
No spray	2.5	2.90	1.8	1.29	0.39
Detergent	0.5	3.23	2.3	1.07	0.66
KCl (F)[2]	0.0	3.18	0.0	1.43	1.01
KCl (F) + D	0.0	3.36	0.0	2.04	1.00
KCl (C)	0.0	3.38	0.0	1.66	0.63
KCl (C) + D	0.0	3.21	0.0	1.40	0.92
K_2SO_4	0.0	3.42	0.0	1.68	1.42
K_2SO_4 + D	0.0	3.32	0.0	1.70	1.19
LSD 5%	0.3	N.S.	0.5	N.S.	0.32
1%	0.4		0.7		0.42

[1] 0 None; 1 slight; 2 severe; 3 very severe
[2] F — Fertilizer grade; C — Analytical grade; D — Detergent

TABLE 3. — INFLUENCE OF KCl SPRAY ON YIELD OF TUBERS AND FOLIAGE AND FOLIAGE NECROSIS OF POTATOES, MATANUSKA VALLEY, 1956 AND 1957

	1956 Tons per acre		1957	
	US No. 1 tubers	Foliage	Plants per 20-ft. row showing foliage breakdown July 11	Tons per acre US No. 1 tubers
	Means of 8 measurements		Means of 64 measurements	
No spray	6.15	3.76	5.6	7.98
KCl spray	13.71	7.55	2.4	10.97
LSD 5%	2.64	0.81	1.4	0.63
1%	3.91	1.20	1.8	0.83

TABLE 4.— EFFECT OF KCl AND K_2SO_4 SPRAYS ON FOLIAGE NECROSIS AND YIELD OF POTATOES, MATANUSKA VALLEY, 1958 AND 1959 (MEANS OF 18 MEASUREMENTS)

	1958		1959	
	Plants per 20-ft. row showing foliage breakdown Aug. 7	Tons/acre US No. 1	Plants per 20-ft. row showing foliage breakdown July 6	Tons/acre US No. 1
No spray	10.6	7.88	4.9	12.55
KCl spray	6.4	9.36	0.0	13.34
K_2SO_4 spray	7.5	9.30	0.2	13.61
LSD 5%	1.4	0.69	1.9	N.S.
1%	1.8	0.92	2.6	

produce a greater yield than muriate of potash sprays. There was no real difference between the fertilizer and analytical grade of muriate of potash (Table 2).

Potatoes

Table 3 presents a summary of data reported in greater detail in previous papers (1, 2). Muriate of potash sprays in 1956 doubled the yield of both vines and US No. 1 tubers. Again in 1957 this spray markedly increased US No. 1 yield and also drastically reduced the number of plants showing foliage necrosis during the period of rapid growth.

The effects of muriate and sulphate of potash sprays on potatoes are compared in Table 4. The number of plants showing foliage breakdown in both 1958 and 1959 were markedly reduced by both potassium sprays. The yield of US No. 1 tubers also was increased in both years by these sprays, although the 1959 increase was not significant. A severe hailstorm on August 6, which almost completely defoliated the vines, may have been responsible for this lack of significance. There were no significant differences between sulphate and muriate of potash sprays.

This work substantiates Prummel's (3) reported 35 per cent potato yield increase with four sprayings of 6 to 10 per cent sulphate and muriate of potash solutions. Preliminary work here shows KCl concentrations exceeding 2 per cent burn the foliage severely while Prummel reports only slight leaf scorching. Sulphate of potash concentrations up to 8 per cent have not injured potato foliage in Alaska.

These potato experiments indicate that frequent muriate or sulphate of potash sprays during the season in Alaska may keep the vines green and markedly increase potato yields when sufficient potassium is not available in the soil. Since higher concentrations of sulphate of potash have not injured potato foliage, future experiments are planned to attempt to further increase yields with frequent highly concentrated sulphate of potash sprays.

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A NEW COMPACT ORCHARD CONCENTRATE SPRAYER[1]

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ABSTRACT

An experimental air-blast, concentrate, orchard sprayer, powered from the tractor power-take-off shaft, has been built and tested. In experiments conducted throughout the spray season, it gave as good insecticide deposits on the leaves of large apple trees as an efficient single-side sprayer having its own engine.

INTRODUCTION

The power for operating the fan and pump units on most air-blast, concentrate sprayers used in British Columbia orchards is provided by a gasoline engine mounted on the sprayer. If the tractor p.t.o. (power-take-off) could be used satisfactorily to supply the required power, the sprayers could be manufactured more cheaply, and sprayer engine maintenance costs would be eliminated. This paper describes an experimental sprayer that was constructed to determine the feasibility of providing power for an air-blast sprayer from the tractor p.t.o. instead of from a separate engine.

DESCRIPTION AND CONSTRUCTION

The experimental sprayer consists of a tractor-mounted unit and a trailed unit (Figure 1). The mounted unit includes a universal drive, gear-box, fan and fan housing, nozzle boom, nozzle control valve, pressure-line strainer and pump. The trailed unit includes the spray tank, suction-line strainer, pressure gauge, pressure relief valve, and suction and pressure hoses. The mounted unit weighs 350 pounds, the trailed unit 450 pounds.

The power to operate the fan and pump is supplied from the tractor p.t.o. shaft through a universal drive and a gear-box. The gear-box provides a step-up ratio of 3.2 to 1. Thus, a speed of 625 revolutions per minute on the p.t.o. shaft gives a fan speed of 2,000 revolutions per minute. The power requirement for the fan, and pump, is about 16 horsepower.

A 15-inch diameter, forward-curved, centrifugal fan of the squirrel-cage type provides the air blast that carries the spray throughout the trees. Experiments with several designs of air outlet indicated that a modified keyhole shape gave the most satisfactory airstream. This outlet has an over-all length of 30 inches. Its width, at 3-inch intervals, from top to bottom, is as follows: 1¾, 2⅛, 2¾, 3⅜, 3½, 3⅜, 3⅛, 2⅞, 2⅜, 1¾ and 1½ inches. The outlet area is about 81 square inches. With this outlet, the fan, when turned at 2,000 revolutions per minute, produces an airstream with an average velocity of 140 miles per hour and a volume of 6,900 cubic feet per minute.

The sprayer has four hollow-cone swirl nozzles, fitted with tungsten carbide orifice disks and swirl plates that give a total output of 1.5 imperial gallons per minute at a pressure of 100 pounds per square inch. Liquid pressure is provided by a diaphragm pump operated at 550 strokes per minute. At this speed the pump delivers about 4.5 imperial gallons per

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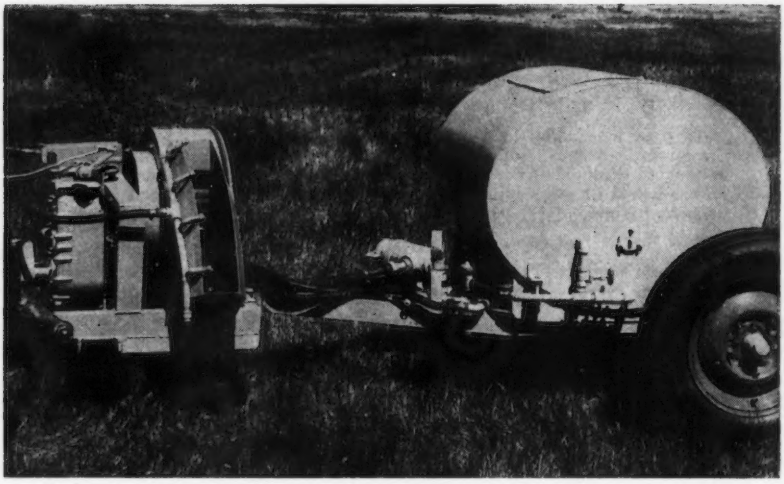

FIGURE 1. Experimental sprayer, showing the mounted and trailed units.

minute at a pressure of 100 pounds per square inch. The spray tank is made of type 302 stainless steel. It holds 100 imperial gallons, sufficient spray liquid to spray 2 acres of mature orchard.

Both hydraulic and mechanical agitation are provided. Hydraulic agitation is used for mixing the spray material when the sprayer is stationary. The output of the pump is returned to the spray tank through a venturi system. The venturi action creates a turbulent flow that results in good agitation of the spray mixture. Mechanical agitation is used when the sprayer is in operation. The agitator shaft is belt-driven from a drum on one of the trailer wheels.

ASSESSMENT

Experiments were conducted throughout the spray season to compare the performance of the experimental sprayer with that of a 1955 Turbo-mist sprayer* that consistently gives good control of orchard insects and diseases. The Turbo-mist sprayer is powered by a 134-cubic inch industrial engine. The air output of this sprayer is 7,300 cubic feet per minute at an average velocity of 120 miles per hour.

Both sprayers were operated at 1 mile per hour and both applied the spray material at the rate of 50 gallons per acre. A pump pressure of 100 pounds per square inch was used with the experimental sprayer, and a pump pressure of 300 pounds per square inch with the Turbo-mist sprayer.

In June each sprayer was used to apply DDT spray to four replicated plots of mature Jonathan apple trees in one orchard, and, in June and August, to replicated plots of mature McIntosh apple trees in a second orchard. In a third orchard, sprays of Ethion and Sevin were applied, with each sprayer,

*Okanagan Turbo Sprayers, Penticton, B.C.

to replicated plots of mature McIntosh apple trees in May and July. In the three orchards the trees, which were 30 feet apart in the rows, ranged in height from 18 to 22 feet, and, in diameter, from 25 to 30 feet.

Leaf samples were picked for insecticide deposit analysis after each spray. Fifty leaves were taken from the top and fifty from the bottom, of each of five trees per plot. Tree-top samples were taken 15 feet above ground level, and tree-bottom samples 6 feet above ground level. Sampling technique and sample treatment were the same as reported by Waddell and McArthur (4). DDT was determined by a modified Schechter-Haller method (2), Ethion by a colorimetric method (1), and Sevin by the Miskus method (3).

RESULTS AND DISCUSSION

The results show (Table 1) that the experimental sprayer gave as good deposits as the Turbo-mist sprayer in the tops of the trees (no significant difference at the 5 per cent level). The Turbo-mist sprayer gave generally higher deposits than the experimental sprayer in the bottoms of the trees, but significantly higher (at the 5 per cent level) in only two of the seven experiments.

The excellent spray coverage obtained with the experimental sprayer shows that it is feasible to use the tractor p.t.o. as a power source for operating a single-side, air-blast orchard sprayer. Most orchard tractors used in British Columbia do not develop sufficient power to operate double-side sprayers capable of spraying large trees. On the other hand, it would be feasible to use the p.t.o. to power a double-side sprayer for spraying orchards of dwarf or semi-dwarf trees.

The sprayer described in this paper has several features that will appeal to fruit growers. Most important of these is low cost. It should be possible to produce, commercially, a sprayer of similar design for approximately $1,000 less than comparable single-side sprayers having a separate engine. Operating costs will be less because of lower fuel consumption, and because there is no sprayer engine to maintain and service. In addition, the light,

TABLE 1. — MEAN INSECTICIDE DEPOSITS ON LEAVES (MMG./SQ. CM.) FROM THE EXPERIMENTAL SPRAYER AND THE TURBO-MIST SPRAYER

Orchard	Experiment	Month and material	Tree tops		Tree bottoms	
			Experimental sprayer	Turbo-mist sprayer	Experimental sprayer	Turbo-mist sprayer
1	1	June, DDT	4.50	4.45	5.67	7.32
2	2	June, DDT	6.00	5.95	6.75	9.70[1]
2	3	August, DDT	8.35	10.40	13.40	17.60[1]
3	4	May, Sevin	4.35	3.20	4.20	4.25
3	5	July, Sevin	2.70	3.10	5.25	5.80
3	6	May, Ethion	3.15	3.80	4.05	4.55
3	7	July, Ethion	2.60	3.05	3.35	4.55

[1]Turbo-mist deposit significantly higher (at the 5 per cent level) than the experimental sprayer deposit

compact p.t.o.-driven sprayer is more manoeuvrable and causes less soil compaction than sprayers having a separate engine.

In 1960 the experimental sprayer was rebuilt, with the same components, as a completely-trailed unit. This change permits using the sprayer with tractors not having a 3-point hitch, makes it easier to provide mechanical agitation when the sprayer is stationary, and allows the nozzles to be placed farther from the operator.

ACKNOWLEDGEMENTS

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INFLUENCE OF SPRINKLER IRRIGATION ON THE INCIDENCE OF WEATHER FLECK ON FLUE-CURED TOBACCO IN ONTARIO[1]

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ABSTRACT

Indices of amounts of weather fleck were evolved from field inspections of flue-cured tobacco subjected to variable amounts of irrigation water. The susceptibility of tobacco leaves to weather fleck increased with maturation, reaching a maximum when they became mature. Occurrence and intensity of the disorder were found to be directly related to amounts of incident water, which hastened leaf maturity and rate of plant growth.

INTRODUCTION

A leaf disorder (Figure 1), commonly known as weather fleck and believed to be physiological in origin, has been a serious problem in flue-cured tobacco production since 1954. The individual spots, irregular in size and shape and generally less than 1/16 inch in diameter (Figure 2), are initially black but later turn brown and eventually greyish-white. In early stages the damage is restricted to the palisade mesophyll, but within 12 hours the upper epidermis breaks down and spots become apparent on the surface. The affected tissue, which persists in the leaves, reduces the marketable value of the cured product.

Observations and preliminary studies in 1957 and 1958 suggested that incidence of weather fleck was related to meteorological conditions and amount of water applied by irrigation. The prevalence of weather fleck on irrigated tobacco led to the supposition that sprinkler irrigation, which has been more generally in vogue since than before 1955, might be accountable for the greatly increased incidence and severity of the disorder. This study was undertaken in 1959 to determine if a relationship exists between amount of weather fleck and incident water.

REVIEW OF LITERATURE

Anderson (1, 2) briefly described three kinds of leaf spots of a similar nature on Connecticut Valley shade tobacco. In recent years non-parasitic leaf spots have become a serious problem on this type of tobacco. Recently, Heggestad (3) obtained good correlation between development of a leaf spot, termed "weather fleck", and high values of ozone; and Taylor (6), in studying the effects of moisture supply upon oxidant injury, found that turgid leaves had more weather fleck than flaccid leaves after exposure to ozone. Fleck appeared only on leaves exposed to ozone. Sand (5) considers that weather fleck in Connecticut shade-grown tobacco involves interaction between genes of the tobacco plant and its environment. He believes that the effects of at least five variables must be known before fleck can be predicted: variety or strain, stage of plant development, cultural environment as it affects leaf physiology, microclimatological factors, and ozone concentration. Lucas (4) classifies non-parasitic leaf spots as due to unbalanced nutrition, toxic agents, or an inherent predisposition to spotting.

[1]Contribution No. 20, Research Station, Research Branch, Canada Department of Agriculture, Harrow, Ont.

METHODS

Seedlings of the variety White Gold were transplanted in quadruplicate treatment blocks on June 5. The plant spacing was 42 inches between rows and 23.75 inches within rows in 8-row plots, 45.5 by 28 feet in size, giving a population of 6300 plants per acre. Details of the irrigation system have been described in a previous publication (7). Natural precipitation was supplemented by irrigation schedules to meet prescribed minimum amounts of 0.5, 1.0, 1.5 and 2.0 inches of water per week for irrigated treatments. Unirrigated plots were used as controls. The weekly irrigation schedules, which commenced on June 23, were discontinued after August 5 because of substantial amounts of rainfall and a decreasing water requirement of maturing tobacco.

Soil moisture was measured by means of plaster of Paris soil moisture blocks buried 6, 12 and 18 inches deep at distances of 0, 6, 12 and 18 inches from the plants. The readings of twelve blocks per treatment were averaged to give the soil moisture for the root zone. Soil moisture measurements were recorded tri-weekly until the middle of August.

Weather fleck was estimated quantitatively on the basis of the number and distribution of spots on affected leaves. A leaf was given the maximum fleck rating of 100 if the spots were distributed over the entire leaf surface in sufficient intensity to render the leaf commercially valueless. Approximately 25 per cent or more of the area of such a leaf would be accounted for as spots. Proportionate ratings were tabulated for those leaves on which the spots were more discrete or distributed over less than 100 per cent of the leaf surface. Average indices of weather fleck per leaf were tabulated from groupings of leaves according to replication, plant location within replication, treatment, and leaf position within treatment according to the formula $I = \frac{(r_1/n_1 + r_2/n_2 + \text{-----} r_x/n_x)}{x}$, where r = sum of fleck ratings on individual leaves and n = number of leaves rated, in each of x plants.

Weather fleck was rated on two groups of five plants (14 leaves per plant) in a single row of each plot four times during the season. In order to study the effect of leaf maturity on incidence of weather fleck, leaves of one group were left on the plants while those of the other group were harvested when mature. To determine the progress of maturation the number of leaves that had reached maturity on each plant was counted at each rating.

RESULTS

Cumulative rainfall and irrigation along with dates of weather fleck occurence in the 1959 season are shown in Figure 3. There were 9.7 inches of rainfall during the period from June 5 to September 15. Schedules requiring minimum amounts of 0.5, 1.0, 1.5 and 2.0 inches per week received totals of 1.5, 4.4, 7.8 and 11.3 inches of supplemental water, respectively. These amounts were applied in four, six, seven, and seven applications for the respective treatments.

FIGURE 1. A leaf of flue-cured tobacco showing severe weather fleck.

FIGURE 2. Portion of a leaf showing both newly formed (*dark*) and aged weather fleck spots.

Weather fleck first appeared in the 2.0, 1.5-, 1.0- and 0.5-inch per week plots on July 17, July 23, August 15 and August 27, respectively, and in the unirrigated plots on September 2. The cumulative rainfall and irrigation water on these respective dates amounted to 8.1, 8.2, 8.6, 9.3 and 9.7 inches.

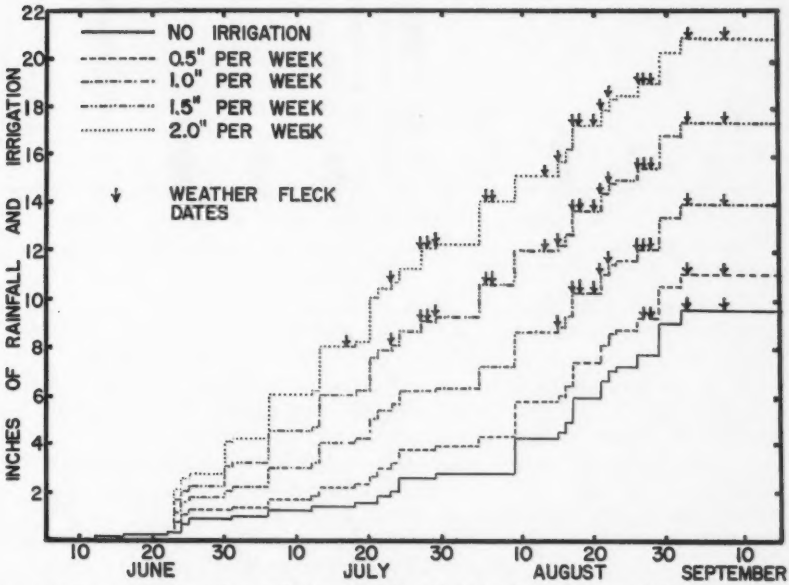

FIGURE 3. Effect of cumulative rainfall and irrigation water on date of weather fleck outbreak.

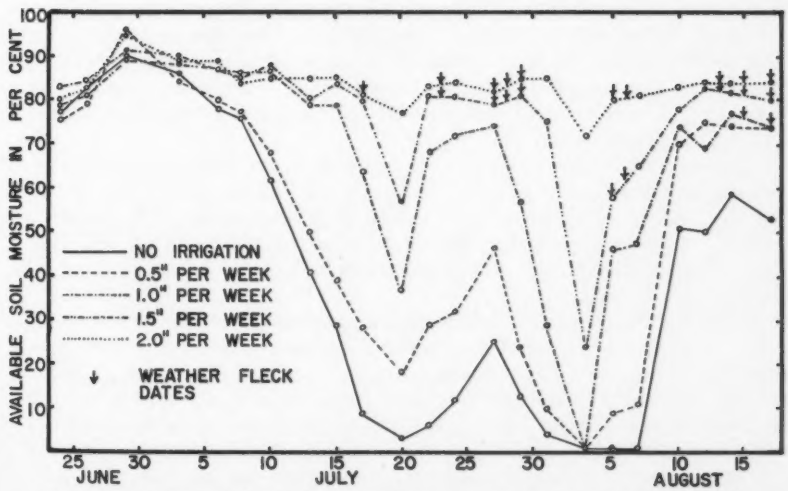

FIGURE 4. Effect of level of soil moisture on occurrence of weather fleck.

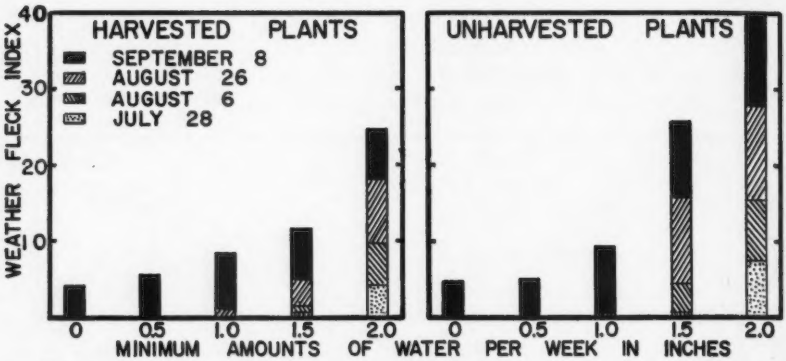

FIGURE 5. Incidence of weather fleck on four dates in harvested and unharvested tobacco grown with different water treatments.

The time of occurrence of weather fleck in relation to per cent available soil moisture is shown in Figure 4. This record of soil moisture covers the rainfall-deficient portion of the 1959 season. Fleck occurred only at the high soil moisture levels until August 17. Reference to Figure 3 reveals that the upward slope of the cumulative rainfall after cessation of irrigation on August 5 is similar to that for the 1.5- and 2.0-inch water treatments prior to August 5. Since the soil moisture was relatively high from the middle of August until early in September, all outbreaks of fleck after August 17 occurred at high soil moisture levels.

The indices of weather fleck for each treatment in Figure 5 are the averages of those from four replications. Irrigation had a pronounced effect on amount of weather fleck. This is indicated by the fact that there was an increasingly higher incidence of the disorder for each increment of water. Harvested and unharvested plants gave comparable results only with water levels up to 1.0 inch per week. The disorder first appeared prior to the July 28th rating in the 1.5- and 2.0-inch per week treatments, between the August 6th and August 26th ratings in the 1.0-inch per week treatment, and between the August 26th and September 8th ratings in the 0.5-inch per week and no irrigation treatments.

Indices were also tabulated for plant location among replications to determine if incidence was affected by distance of the plant from the plot border. Analysis of variance indicated that replication and location of plants within replications had little or no effect on the incidence of weather fleck, whereas differences between treatments were well below the 1 per cent level of significance.

The indices of fleck at different leaf positions are shown in Figure 6. These values, which are the cumulative totals for the entire season, are separated in Figure 7 to show the indices on each of four dates during the season. On each rating date, except for the initial rating on July 28, the reported indices are the difference between the observed indices and those for the previous rating date. Data from harvested plants were omitted from the latter comparison as the results were biased by the harvesting of leaves. Each index value shown in Figures 6 and 7 represents the average of 20 leaves.

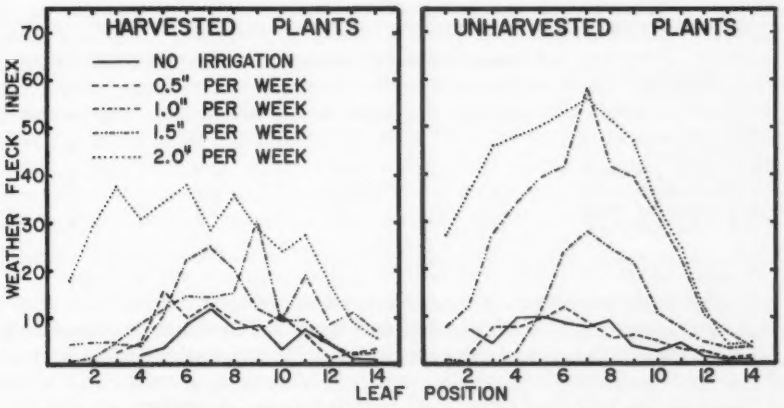

FIGURE 6. Weather fleck in relation to leaf position and water treatment in harvested and unharvested tobacco.

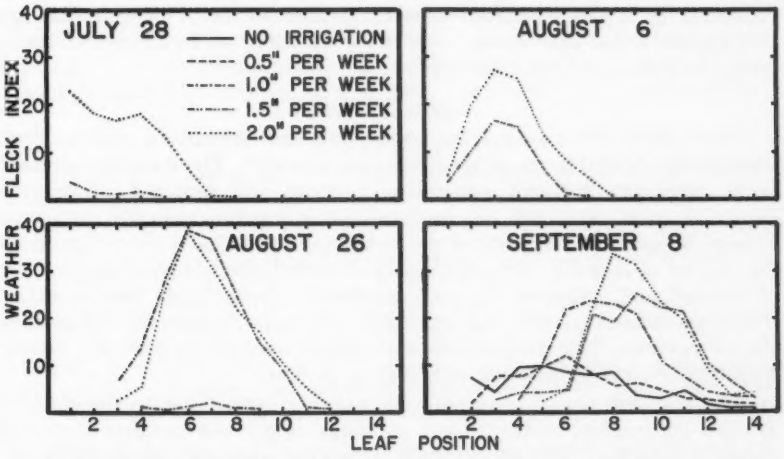

FIGURE 7. Incidence of weather fleck in relation to leaf position and water treatment in unharvested tobacco on four dates.

Figure 6 shows the weather fleck was most prevalent on leaves at intermediate stalk positions in all treatments, especially in those receiving 1.0 or more inches of water per week. Harvested and unharvested plants gave similar results only at water levels up to 1.0 inch per week.

From Figure 7 it would appear that the incidence of weather fleck is related to leaf maturity, as the peak in intensity occurred at successively higher leaf positions during the season. Also, there was lower incidence at any one leaf position in low as compared with high water treatments.

The average number of mature and overmature leaves per plant in each treatment during the season is shown in Table 1. The data show that water

TABLE 1. — EFFECT OF ACCRUED WATER ON MATURITY OF LEAVES

Treatment	Average number mature and overmature leaves per plant			
	July 28	August 6	August 26	September 8
No irrigation	—	—	3.3	7.4
0.5 inches per week	—	—	2.9	6.2
1.0 inches per week	—	1.6	4.6	8.8
1.5 inches per week	0.7	3.3	7.4	10.9
2.0 inches per week	1.1	4.3	7.8	10.9

promotes early maturity. A comparison of the average numbers of mature and overmature leaves with the data in Figure 7 shows a close relationship between these numbers and the peaks in intensity of weather fleck. In most cases the concentration peak for a particular date is only one or two leaves lower than the leaf of ideal maturity on that date. As indices on any date are for all fleck occurring since the previous rating, this relationship is to be expected if incidence of fleck is related to leaf maturity. Mature leaves were recorded for low and medium water treatments on dates when no damage was reported, but ripe leaves were always affected when the water application was above 1.0 inch per week.

DISCUSSION

This study indicated that the occurrence and intensity of weather fleck was directly related to the incident amounts of water. The disorder increased in the aggregate for each increment of water, and appeared 1½ months earlier in plots receiving the maximum as compared with the minimum amount of water. The time of the initial appearance seemed to depend on the amount of accrued water, since fleck occurred after almost equal amounts of rainfall and irrigation in each treatment. Such small but consistent differences among treatments are possibly only an indication that the relative loss of moisture from small amounts of rainfall over a long period is greater than that from large amounts over a short period.

Leaves were found to become increasingly more liable to the disorder as they approached maturity and correspondingly less so after they had passed that stage. Therefore, since it hastens maturity, irrigation is undoubtedly closely related to the incidence of fleck.

A higher incidence of the disorder on leaves at mid-position on the stalk suggests that leaves in that location are most readily affected. However, such a phenomenon may indicate only that all parts of the plant are not equally susceptible to the disorder at or for the same period of time. Since leaves mature more slowly progressively up the stalk, the lowermost leaves are in a susceptible maturing state for a shorter period than those at mid-point on the stalk. Failure of the upper leaves to reach full maturity during the course of this study explains why they had relatively small amounts of fleck.

On mature leaves incidence of weather fleck was always greater under high rather than low water treatments. Leaves in the latter treatments often

were under a susceptible maturing state for a considerable period without being affected. Therefore, irrigation practice may contribute to the development of weather fleck irrespective of its effect on leaf maturity. Further evidence of such a complementary effect is provided in the comparison of harvested and unharvested plants, where harvesting was found to be more effective in reducing the amount of fleck in high- than in low-water treatments. This additional effect may be the result of the obvious increase in rate of plant growth and development by irrigation. Maximum rates of plant growth and development would likely occur on flecking dates, since soil moisture was high on these occasions (Figure 4).

In spite of the aforementioned relationships, fleck occurrence was discontinuous rather than continuous at times of maximum susceptibility, and there was a wide variation in its incidence and severity among leaves of corresponding position, maturity and water treatment. Although the nature of the exact cause is a matter of conjecture, there are several promising fields of study. Meteorological conditions may be important from the standpoint of their effect on leaf physiology and nutrition or on the presence of concentration of air pollutants. Ozone has been postulated by Heggestad (3) to be the cause of weather fleck on Connecticut shade-grown tobacco. Weather fleck may be the final expression of a complex interrelationship between the plants, and elements of the environment such as cultural practices, meteorological conditions, and toxic ingredients in the atmosphere.

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EFFECT OF A HIGH WATER CONTENT IN STORED WHEAT, OAT, AND BARLEY SEED ON ITS GERMINABILITY, SUSCEPTIBILITY TO INVASION BY MOULDS, AND RESPONSE TO CHEMICAL TREATMENT[1]

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ABSTRACT

The rate at which germinability is lost in untreated wheat, oats and barley grain was found to depend chiefly on its water content and on the temperature at which it is stored. Germinability of treated grain also depends on other factors, such as the chemical used for seed treatment and the kind of grain treated. The total reduction in germination was dependent on the duration of storage. Grain which had been wet, but was dried by the time of treatment, showed about the same degree of chemical injury as grain that had not been wet.

When grain produced in Western Canada, where it is generally infested by a wide variety of fungi of which *Alternaria tenuis sensu* Wiltshire is the most common, was stored untreated and in a moist condition, this fungus became overgrown by species of *Rhizopus*. When, however, the moist grain was treated with Ceresan M before it was stored, the *Alternaria* was often displaced by one or more species of *Penicillium*. The source of the grain did not seem to affect the ultimate type of fungus growth appearing on it.

Chemical treatment often impaired the germination of grain that was only moderately damp and did not prevent deterioration of grain that was very damp. Pre-storage treatment of smut-free grain is, therefore, not recommended.

INTRODUCTION

In Western Canada, as in other grain-producing areas, dampness in threshed grain is a perennial problem fluctuating in importance from year to year. The problem is important because grain with a high water content tends to mould or otherwise spoil in storage. This results in a lowering of the baking, malting, and feeding quality in commercial grain, and in a reduced viability in seed grain. In addition, a high water content in grain increases its susceptibility to injurious action from the chemicals used for treating seed.

The object of the present investigation was to determine the relative importance of various factors causing reduced germination in stored seed grain, and to define their interaction. To accomplish this, it was necessary in some cases to repeat the experiments carried out by earlier workers. Most of the information was gained, however, from original work, especially from that with seed treated with products not available when the earlier work was done.

REVIEW OF LITERATURE

Low germination of damp grain, after a period of storage, has been attributed by earlier workers to a number of factors, the most important of which seem to be mould (9, 10, 11, 12, 13, 16, 19, 20, 24, 28, 29, 30, 34,

[1]Contribution No. 67, Canada Department of Agriculture Research Station, Winnipeg, Man. (Co-operative investigation by the Research Branch and the Plant Products Division, Canada Department of Agriculture).

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36, 38) and improper seed treatment (1, 3, 5, 7, 20, 33, 34). The impact of these two main factors depends on the magnitude of the influence of accessory factors, such as on the amount of mechanical injury to the seed (20, 26, 32, 41) and on its water content (1, 4, 7, 8, 11, 18, 22, 27, 30, 31, 34). Both of these accessory factors affect the severity of mould and chemical injury to the seed.

The chemicals that injure seeds most commonly are organic mercury compounds, hexachlorocyclohexane, and formaldehyde. The two materials first mentioned cause a hypertrophy of the roots and plumule, but all tend to weaken the seedlings arising from treated seed. If the exposure of the seeds to the chemical is prolonged (21, 22), or if there is an overdose (1, 3, 7, 22), the treated seed may be killed. Unsuitable conditions of storage, especially high atmospheric humidity (1, 7, 17, 34) and high temperature (40), reduce the viability of treated seed. The condition of the seed itself, especially its water content (3, 5, 7, 21, 22, 33), the severity of mechanical injury (20), the degree of its weakening by mould (1), and its general physical condition (26), affect the degree of chemical injury. So do other factors, such as the kind of crop treated (3, 7, 22).

Seeds of the small grains when produced in the open are usually infected by one or more species of fungi (25, 38). They are to be found in the pericarp, the embryo, the aleurone layer, and the endosperm (11, 12, 31, 38). When the seed is put into storage while wet, the "normal" fungus flora – *Alternaria* spp. predominating – is overgrown by species of *Aspergillus* or there is some other succession (28, 29, 37). Thus, species of *Alternaria* would seem to be the chief contaminants of high grade seed, while species of *Aspergillus* and *Penicillium* predominate in low-grade seed (9). If the water content of the grain is very high, the grain may ferment and its microflora may then consist of yeasts (1, 23). Invasion of the seed by moulds results in its deterioration (12, 38), and seed from different areas may differ in the pattern of its deterioration. Exposure of the seed embryo and other forms of mechanical injury predispose grain to moulding (20, 22, 41). Some investigators (2, 30, 31, 33, 34, 35) have reported that mouldiness may be reduced or prevented by suitable seed treatment, but there were exceptions (1, 33).

MATERIALS AND METHODS

The experiments described in this paper were carried out during the period 1951-1955 and, with few exceptions, they were carried out under controlled laboratory or greenhouse conditions.

The crops investigated were wheat, oats, and barley, mostly of "Certified" or "Registered" status. The material used for a study of intra-varietal variation in the response of moist grain to chemical treatment consisted of 61 two-pound samples of Selkirk and 50 samples of Thatcher wheat obtained directly from the growers. The material used for a study of the response to treatment of grain that is dried shortly after it becomes wet consisted of samples taken from carloads of commercial grain inspected and graded at Winnipeg.

Since most of the experiments described in this paper were concerned with the interaction between grain condition and storage environment, the grain for these experiments was prepared as follows: It was first spread on a table and left until its temperature reached that of the room. The water content was then determined by means of a Halross "Moisture Meter" and the weights of water and grain to provide 1-pound aliquots of grain at each of the water-content levels needed were calculated. The grain and water were put together in clean, 1-quart glass jars which were capped and then shaken by hand at intervals until all the free water in the jars was absorbed by the grain. The jars of grain were subsequently held at room temperature for 2 days to allow the moisture of the grain and that of the air in the jar to reach an equilibrium. The grain was now ready for treatment and storage as required for various experiments.

To reduce the dosage error associated with the weighing of very small amounts of chemicals, the grain was treated either in pound lots, or with chemicals in diluted form.

The seed treatments studied were the following:

Check — No chemical applied to seed.

Abol — A powder containing 50.0 per cent hexachlorocyclohexane. The dosage was 1.6 ounces per bushel of wheat and 1.3 ounces for oats and barley.

Agrox C — A powder containing 7.0 per cent phenyl mercury acetate and 1.0 per cent ethyl mercury chloride. The dosage was 0.5 ounce per bushel.

Bunt-No-More — A powder containing 40.0 per cent hexachlorobenzene, applied at the rate of 0.5 ounce to a bushel.

Ceresan M — A powder containing 7.7 per cent ethyl mercury p-toluene sulphonanilide. Applied to seed at 0.5 ounce to a bushel.

Ceresan M — Diluted 1:2 by volume with talc, and applied to seed "in excess". The excess was screened off.

Leytosan G.91 — A powder containing 43.0 per cent hexachlorocyclohexane and 2.5 per cent phenyl mercury urea, applied at 2.0 ounces per bushel to wheat and 1.45 ounces to oats and barley.

Mergamma C — A powder containing 40.0 per cent hexachlorocyclohexane, 2.86 per cent phenyl mercury acetate and 0.4 per cent ethyl mercury chloride, applied to seed at the same rate as Leytosan G.91.

Merlane — A powder of the same composition as Mergamma C but with a different diluent. The dosage was the same as that for Leytosan G.91.

Orthocide 75 — A powder containing 75.0 per cent captan. The dosage was 0.75 ounce per bushel.

Spergon SL — A powder containing 95.0 per cent tetrachloro-para-benzoquinone. The dosage was 2.0 ounces per bushel.

Tests of the germinability were made in incubators, the seed being placed either between sheets of blotting-paper moistened with water or on moistened Whatman filter paper (No. 3) in Petri dishes. In some tests, the seed was sown in large beds of unsterilized soil in the greenhouse. The blotting-paper test (25 seeds in each of four Petri dishes) was used chiefly

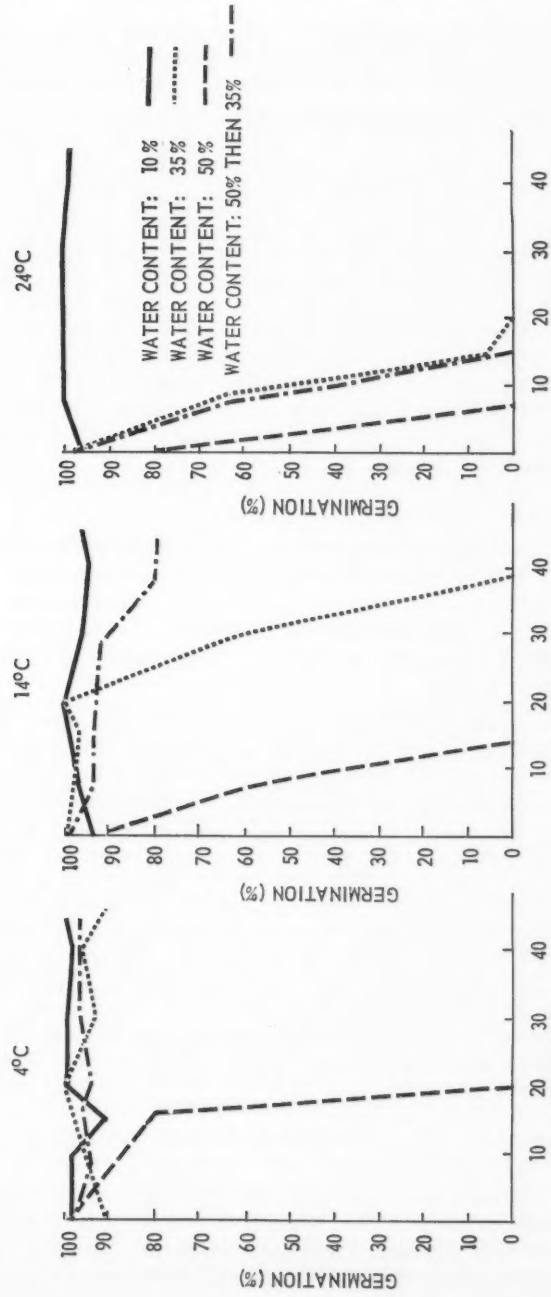

FIGURE 1. Course of loss of germinability in untreated wheat seed at different levels of water content and storage temperature.

for observations on the development of mould, and the soil-bed test (two sowings of 100 seeds each) was used for tests of germination and for a special study of the phytotoxicity of hexachlorocyclohexane when in contact with soil. The period of incubation was 7 days for seed in the laboratory experiment and 10 days for seed sown in soil. The temperature at which the seed was germinated was approximately 20°C.

In several experiments, a portion of the seed studied was stored in open glass jars and another portion in closed jars. As this seed varied in its initial water content, and as each of the closed jars was opened at least twice during the experiment, the gain and loss of moisture was determined for each of 192 jars of wheat stored for 28 days. It was found that seed with an initial water content of 10 per cent tended to absorb some water when kept in open jars and to lose some when kept in closed jars. Seed with an initial water content of 15 per cent changed very little, whereas seed with 18.5 per cent water tended to lose some water in both open and closed jars. The largest loss of water among the 192 jars of seed tested was 1.2 per cent, while the largest gain was 3.5 per cent. The fact that the humidity of the storage room was nearly 100 per cent may account for the small or no loss of water from the open jars.

Deviations from the technique described above are mentioned in connection with the appropriate experiments.

EXPERIMENTAL RESULTS

Effect of the Water Content of Seed and the Temperature of Storage on Germination in Wheat

A preliminary study, in which samples of untreated wheat seed of several water contents were stored at three temperatures in closed glass jars for 44 days, showed that both the water content of seed and the temperature at which it is stored affect its survival in storage. As Figure 1 shows, seed with a water content of about 10 per cent retained its viability at all three temperatures (4°C., 14°C., 24°C.) for the full period of storage. Seed with a water content of 35 per cent kept its viability when stored at 4°C., but its germination declined rapidly after storage for 20 days at 14°C. and very rapidly, from the beginning of storage, when the temperature was 24°C. Seed with a water content of 50 per cent lost its germinability quickly at all three temperatures, but if such seed was dried for 2 days to a water content of 35 per cent, it kept well at 4°C., and 14°C., but deteriorated rapidly at 24°C. Ungerminated kernels were in most cases overgrown by *Rhizopus* spp. and in grain with 35 or 50 per cent water they were also overgrown by yeasts.

The Water Content of Grain at the Time of Threshing in Relation to the Occurrence of Threshing Injury

A study of data collected during an examination of wheat from each of nearly 200 different carload lots inspected at Winnipeg, in 1950, showed a negative correlation between the water content of the grain and the percentage of fractured kernels. Although the coefficient of correlation

was only −0.366, which may have been due in part to the time the crop became damp, it was statistically significant and indicated that moist kernels are less subject to mechanical injury than dry kernels.

Effect of Various Seed Treatment Products on Seed Germination in Wheat, Oats and Barley

In a preliminary experiment to determine the effects of pre-storage chemical treatment on the germination of wheat, oat and barley seed after 28 days in storage under different conditions, it was found that Ceresan M increased germination in oats, but not in wheat or barley, Mergamma C lowered germination in all three grains, whereas Bunt-No-More had no effect. A larger experiment was therefore set up to compare the effects of Ceresan M, Bunt-No-More, Orthocide 75, Spergon SL, Mergamma C, Agrox C, and Abol on seed of wheat, oats, and barley, each with 10, 20 and 30 per cent water content at 10° and 20°C. for 28 and 56 days. In this experiment only wheat was affected by seed treatment. No treatment increased germination, but Mergamma C and Abol reduced it, particularly in seed with a water content of 20 or 30 per cent. The interaction of seed treatment and other factors with respect to seed germination of wheat are shown in Table 1. These data indicate that, while untreated seed may germinate well at the beginning of storage, even when its water content is 30 per cent, its viability declines quickly in storage if its water content is 20 per cent or more. The decline is more rapid at 20°C. than at 10°C. and, after 56 days in storage, all of the seed which at the beginning of storage contains 30 per cent water may be dead. The germination pattern for treated seed closely resembles that for untreated seed, that is, its germination decreases as its initial water content, and the temperature and duration of storage, increases. None of the treated seed which initially had a water content of 30 per cent survived a 56-day storage period at 10°C. and 20°C. nor did any of it survive for 28 days at 20°C. Some treated seeds survived for 28 days at 10°C. but the percentage of survivors depended on the kind of pre-storage treatment the seed received.

The treated seed produced some seedlings characterized by swollen stubby roots and plumules, as described by Crosier (14) and others. These deformed seedlings occurred most often in wheat, less often in oats, and least often in barley. In wheat, the seed dressings responsible for the deformity, in decreasing order of phytotoxicity, were Mergamma C, Abol, Ceresan M, and Agrox C. The percentage of deformed seedlings was highest in seed with an initial water content of 30 per cent, less for seed with 20 per cent, and least for seed with 10 per cent. There was more deformity among seedlings from seed stored at 20°C. than from seed stored at 10°C. and the amount increased with the duration of storage.

A larger percentage of deformed seedlings occurred when treated seed was germinated on moist paper than when it was germinated in soil. Experiments with wheat seed treated with Abol showed that soil reduced the phytotoxic action of hexachlorocyclohexane. It was found that, when the dose of Abol was kept constant, treatment of seed with Abol alone resulted in a much higher percentage of deformed seedlings than when the seed

TABLE 1.—EFFECT OF THE WATER CONTENT OF SEED, AND OF THE TEMPERATURE AND DURATION OF STORAGE, ON THE PERCENTAGE OF NORMAL SEEDLINGS FROM WHEAT SEED TREATED WITH VARIOUS SEED DRESSINGS

Water content of seed	Seed dressing	Storage temperature 10°C.			Storage temperature 20°C.		
		Normal seedlings at beginning of storage (%)	Normal seedlings after storage for 28 days (%)	Normal seedlings after storage for 56 days (%)	Normal seedlings at beginning of storage (%)	Normal seedlings after storage for 28 days (%)	Normal seedlings after storage for 56 days (%)
10%	None	87	87	95	92	85	91
	Abol	91	82	72	85	72	82
	Agrox C	96	93	95	97	95	88
	Bunt-No-More	90	90	91	98	91	85
	Ceresan M	94	92	82	96	82	78
	Mergamma C	76	75	58	62	58	33
	Orthocide 75	94	94	95	94	95	94
	Spergon SL	92	89	92	92	92	96
20%	None	92	84	80	95	76	64
	Abol	85	79	78	82	60	26
	Agrox C	92	89	78	93	91	82
	Bunt-No-More	91	90	65	96	82	81
	Ceresan M	94	87	84	95	91	7
	Mergamma C	55	49	28	62	23	9
	Orthocide 75	93	93	91	96	92	86
	Spergon SL	89	85	93	90	70	65
30%	None	88	71	0	94	0	0
	Abol	24	15	0	33	0	0
	Agrox C	91	59	0	89	0	0
	Bunt-No-More	92	74	0	94	0	0
	Ceresan M	75	30	0	78	0	0
	Mergamma C	8	0	0	0	0	0
	Orthocide 75	92	60	0	93	0	0
	Spergon SL	90	1	0	89	0	0
Significant difference		5.6 at 5% level; 7.2 at 1% level					

was treated with a mixture of soil and Abol. When seed treated with Abol alone was held for 12 days, and when seed so treated was mixed with soil immediately before a test of germination was made, all the resulting seedlings were deformed. When, however, the treated seed was kept for a week in dry soil or sand, or in various mixtures of soil and sand, the percentage of deformed seedlings was greatly reduced. It was found also that when untreated wheat seed was kept in dry soil containing various proportions of Abol, the concentration of Abol had to be at least 2.5 per cent before there was any immediate effect on the seed, and that the percentage of affected seeds decreased as the duration of their contact with treated soil increased.

As grain sometimes becomes wet after it is threshed, and after being dried is used for seed purposes, an attempt was made to measure the effect of

TABLE 2.—EFFECT OF KIND OF SEED TREATMENT ON SEED GERMINATION AND THE DEVELOPMENT OF FUNGI IN WHEAT GRAIN AT TWO LEVELS OF WATER CONTENT AND STORED AT TWO TEMPERATURES

Duration of storage (weeks)	Seed not treated				Seed treated with Ceresan M				Seed treated with Orthocide 75				Seed treated with Abol			
	4°C.[1]		24°C.[2]		4°C.		24°C.		4°C.		24°C.		4°C.		24°C.	
	12%	34%	12%	34%	12%	34%	12%	34%	12%	34%	12%	34%	12%	34%	12%	34%
	Germination, per cent of normal seedlings															
0	96	100	90	100	98	100	98	100	100	98	100	100	100	100	100	98
1	98	96	98	96	98	100	100	73	98	96	92	84	98	98	96	74
2	94	94	98	0	92	98	98	0	98	100	100	0	96	100	98	0
4	96	80	96	0	98	96	96	0	98	96	98	0	100	76	94	0
8	100	10	94	0	100	92	96	0	98	64	96	0	100	0	100	0
12	100	0	98	0	100	80	98	0	98	40	100	0	98	0	98	0
	Alternaria tenuis, per cent of seeds infected															
0	66	4	76	4	0	0	0	0	6	0	10	2	46	4	52	8
1	60	4	28	0	0	0	0	0	12	2	12	0	54	0	56	0
2	42	2	36	0	0	0	0	0	4	0	2	6	48	0	30	0
4	48	4	46	0	0	0	0	0	8	6	2	0	38	0	50	6
8	36	5	36	0	0	0	0	0	0	10	0	0	11	0	32	0
12	10	0	4	0	0	0	3	0	0	3	0	0	4	0	5	0
	Rhizopus spp., per cent of seeds infected															
0	6	0	4	2	0	0	0	0	0	0	0	0	0	0	0	2
1	4	0	0	20	0	0	0	10	0	0	0	4	0	2	2	23
2	0	2	3	46	0	0	0	34	0	0	0	6	0	0	0	44
4	0	2	0	34	0	0	0	22	0	4	0	2	0	12	0	30
8	0	16	0	34	0	0	0	36	0	16	0	18	0	12	0	16
12	1	12	0	35	0	0	0	40	0	6	3	16	0	16	3	50
	Penicillium spp., per cent of seeds infected															
0	12	2	6	0	0	0	0	0	0	0	0	0	0	0	0	0
1	2	4	0	0	0	0	0	2	0	0	0	0	0	0	0	0
2	0	0	0	6	0	4	0	2	0	0	0	0	0	2	0	4
4	0	2	0	3	0	0	0	12	0	0	0	0	0	2	0	10
8	2	20	0	4	0	50	0	12	0	2	0	0	0	58	0	0
12	0	50	0	26	0	18	0	37	0	3	0	0	0	41	2	42
	Helminthosporium sativum, per cent of seeds infected															
0	0	0	0	0	0	0	0	0	2	0	0	0	4	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0	2	0	4	0
2	0	2	4	0	0	0	0	0	4	2	0	0	0	0	2	0
4	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0
8	0	0	0	0	0	0	0	0	2	0	0	0	6	0	4	0
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

[1]Storage temperatures
[2]Water content

seed treatment on the germination of such dried grain. A large number of samples of wheat, oats, and barley, each sample representing a carload lot of grain graded as "Straight-grade", "Tough", or "Damp", were obtained from the grain inspection office (Board of Grain Commissioners for Canada) at Winnipeg. These samples contained various amounts of water at the time the grain was inspected but, by the time (2 to 3 months later) they were used in the present study, they all had about the same water content – less than 14 per cent. A portion of each sample was treated with dry, diluted Ceresan M and sown along with untreated grain from the same sample in a bed of unsterilized soil in a greenhouse. This test

TABLE 3.—EFFECT OF TREATMENT WITH CERESAN M ON THE GERMINATION OF STORED MOIST SEED[1], AND ON THE PERCENTAGE OF KERNELS INFECTED BY PENICILLIUM OR RHIZOPUS

Treatment	Seed weight[2]	Wheat variety	Percentage of kernels producing normal plants	Percentage of kernels infected by *Penicillium*	Percentage of kernels infected by *Rhizopus*
Untreated	Light	Selkirk	56.0	4.6	24.6
		Thatcher	47.8	13.4	12.8
		(Mean)	(51.9)	(9.0)	(18.7)
	Heavy	Selkirk	50.6	4.0	24.6
		Thatcher	54.6	12.0	14.6
		(Mean)	(52.6)	(8.0)	(18.6)
Treated	Light	Selkirk	71.4	34.6	2.0
		Thatcher	63.4	31.4	2.4
		(Mean)	(67.4)	(33.0)	(2.2)
	Heavy	Selkirk	69.4	25.4	1.2
		Thatcher	65.4	31.4	2.6
		(Mean)	(67.4)	(28.4)	(1.9)

[1]Water content 35 per cent
[2]Variety Selkirk — light seed, 8.2 to 11.4 gm. per 300 kernels; heavy seed, 11.5 to 14.0 gm. per 300 kernels. Thirty lots of light seed, thirty-one lots of heavy seed.
Variety Thatcher — light seed, 4 to 6.8 gm. per 300 kernels; heavy seed 6.9 to 12.0 gm. per 300 kernels. Twenty-seven lots of light seed, twenty-three lots of heavy seed. The difference between varieties in seed weight was due mainly to the effect of leaf rust infection on Thatcher.

showed that in about 80 per cent of the samples, treatment of the seed improved germination between 10 and 30 per cent and occasionally by 100 per cent. This proportion was not affected appreciably by either the kind of grain or its wetness at the time of inspection. In oats and barley, but not in wheat, there was a tendency for the originally moist grain to show less treatment injury than shown by the originally dry grain.

All the experiments with seed treatments described so far in this paper were carried out with only small lots of seed. To obtain information on the reaction of large amounts, bushel samples of wheat seed, each with a water content of more than 17 per cent, were drawn in late February from farm stocks at nine points in Saskatchewan and Alberta. These samples were put in bags, and treated with Ceresan M powder. They were then buried in the bins of seed from which they were originally taken, and left there for 3 months. Tests of germination on this seed before and after storage showed that the mean germination for the untreated seed (nine lots) was 54.3 per cent before storage and 54.2 per cent after. The corresponding percentages for the treated seed were 66.7 per cent and 64.8 per cent. It is evident from these percentages that, under the conditions of this experiment, conditions approaching those to be found in ordinary farm practice, treatment of the moist seed before storage did not harm it. It is suggested that, on the basis of the evidence presented in Figure 1 and Table 1, the retention of germinability in this case was due more to the low temperature associated with winter storage than to seed treatment.

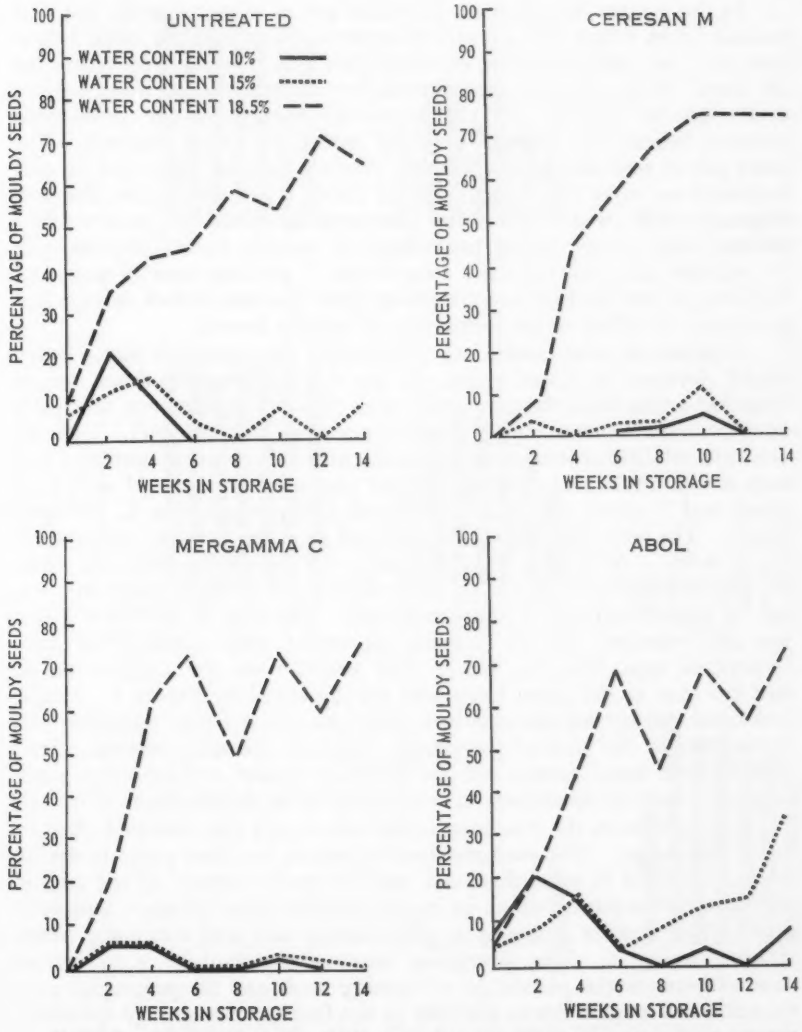

FIGURE 2. Effect of three levels of water content on mould development in treated and untreated wheat seed in storage.

Factors Affecting the Development of Mould in Stored Grain

Wheat, oat, and barley seed produced in Canada carries internally a wide variety of fungi (25). These fungi, many of which also occur as air and soil contaminants, usually do the seed no harm, but under favourable conditions their growth may discolour the seed or decrease its viability, or both.

In the present investigation, microbial action in stored grain was first noticed when wheat seed of various water contents (10 per cent, 15 per cent, 18.5 per cent) was kept in closed glass jars at room temperature for 135 days. When the jars were opened, it was noted that all those holding seed originally with 18.5 per cent water contained gas under considerable pressure, because the closures came off explosively when loosened. The other jars of seed seemed unaffected. When some seed from each jar was incubated on moist filter paper in Petri dishes, it was found that the seed originally with 10 per cent water contained up to 1.5 per cent mouldy kernels. The corresponding percentages of mouldy kernels in seed with 15 per cent and 18.5 per cent water were 13 per cent and 75 per cent. Variation in the kind of seed treatment given the seed before storage had practically no effect on the percentage of mouldy kernels.

Experiments were carried out to determine the conditions under which mould develops in stored grain. In the first experiment, three lots of Thatcher wheat from the same stock were adjusted so that each one had a different water content (10 per cent, 15 per cent, 18.5 per cent). Each lot was then subdivided into seven parts, one of which was left untreated and each of the others was given a different treatment (Ceresan M used a ½ ounce and 1 ounce per bushel, Leytosan G.91, Mergamma C, Merlane, Abol). The seed was then stored in closed glass jars at room temperature for 14 weeks. At weekly intervals during this period, the seed was tested for germination by sowing it on moist filter paper in Petri dishes and in a bed of unsterilized soil in the greenhouse. The seed in the Petri dishes was also examined for the presence of mould fungi (*Aspergillus* spp., *Penicillium* spp., *Rhizopus* spp.). The results from the examination of seed for four of the seven treatments are illustrated by Figure 2. Mould developed quickly and abundantly in seed with 18.5 per cent water content, irrespective of the kind of pre-storage treatment the seed received. Seed with a lower water content did not mould as readily, and there was some difference between treatments in their effect in the development of mould.

Figure 3 shows the condition of the wheat seed just discussed after 14 weeks in storage. The seed-germination pattern on filter paper is similar to that obtained in unsterilized soil and the water content of the seed is shown to have a marked effect on its germinability after storage – seed with a low water content retaining its germinability and seed containing much moisture losing it. The illustration shows also that there is an inverse relation between the percentage of mouldy seeds and the percentage germination and it again draws attention to the fact that pre-storage treatment of the seed fails to prevent the development of mould in the seed if its water content is high enough.

Although it is often taken for granted that mouldy seeds will not germinate, it is difficult to establish that the mould itself is responsible for the loss of germinability. Since seed treatment fails to arrest the development of mould, it may be argued that mould fungi invade the kernel after it has been killed by some other agency.

A study was made of the effect of the water content of the seed and of the storage temperature on the survival of two fungi which normally

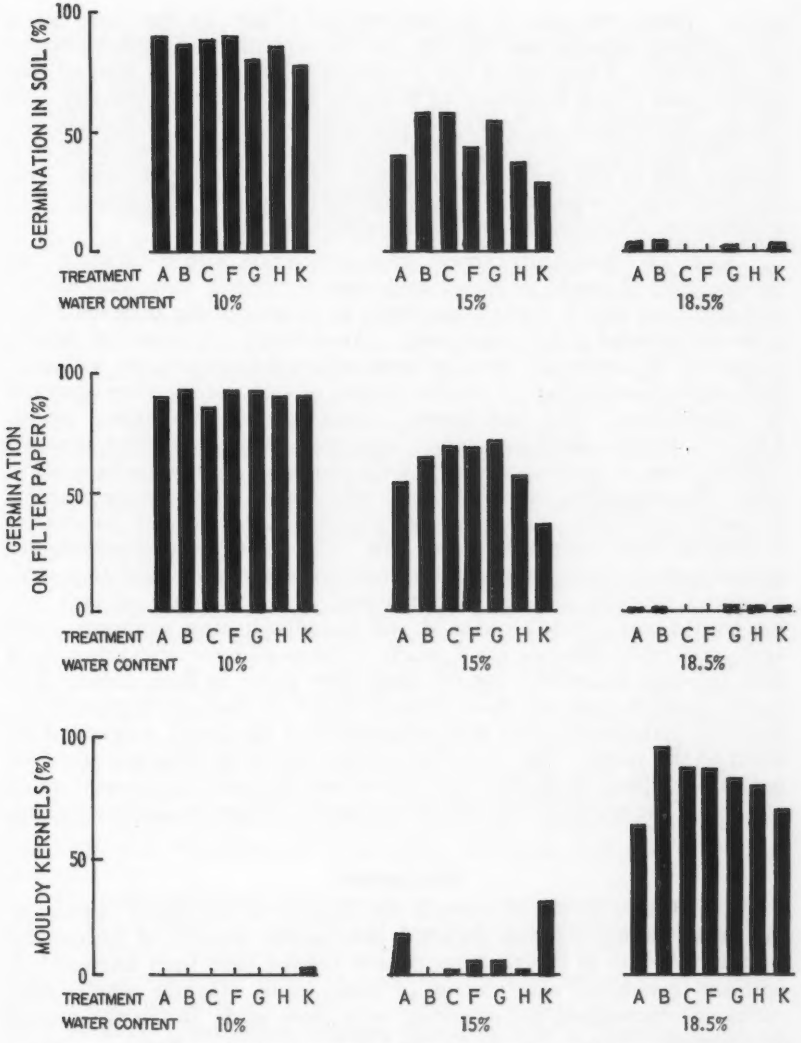

FIGURE 3. Effect of three water contents and seven seed treatments on seed germination and on the occurrence of mould in wheat seed treated before storage and stored for 14 weeks in closed jars at room temperature. Treatments: A, Check; B, Ceresan M (½ oz./bu.); C, Ceresan M (1 oz./bu.); F, Leytosan G. 91; G, Mergamma C; H, Merlane; K, Abol.

occur in newly-threshed seed. One of these fungi, *Alternaria tenuis sensu* Wiltshire, is usually a saprophyte, while the other, *Helminthosporium sativum* P. K.& B., is often parasitic. In this study, samples of wheat seed with 12 per cent and 34 per cent water were stored at 4°C. and 24°C. for 12

weeks. Plating-out tests of the seed showed (Table 2) that there was a close relation between seed viability and the percentage of kernels infected by *A. tenuis*. There was a low frequency of infection in seed of low viability and a high frequency of infection in seed of high viability. As the seed deteriorated, *A. tenuis* was gradually displaced by *Penicillium* spp. and *Rhizopus* spp. It is suggested that the associated lowering of seed viability and of the decreasing frequency of infection by *A. tenuis* have the same cause – exposure to toxic metabolic products of *Penicillium*. The experimental results for *H. sativum* were inconclusive.

Since the experiments carried out in connection with the study of the development of mould in stored seed were performed with only one or two stocks of seed it seemed imperative to determine the variation likely to be encountered in a broader study. Accordingly, 61 samples of Selkirk wheat and 50 samples of Thatcher were collected from growers in Canada and prepared for testing. First, the samples of each variety were separated into two classes, "light" and "heavy", based on their 1,000-kernel weight. This was done to ascertain whether large seeds, which have been reported (26) as prone to mechanical injury, were also prone to invasion by moulds. After the separation, two 300-kernel sub-samples were put in separate, stoppered test-tubes. Enough water was then added to each sub-sample to bring its water content to 35 per cent. The test-tubes were periodically shaken until all the free water in them was absorbed by the seed, then were stoppered air-tight. A day later, the seed in one test-tube of each pair was treated with diluted Ceresan M, and immediately after treatment – and again at weekly intervals for 5 weeks – 50 seeds were withdrawn from each test-tube and plated out on moist filter paper in Petri dishes. The results obtained from this study showed (Table 3) that, while treated seed generally germinated better than untreated seed, the kernel weight had no effect on this trend. The results showed also that *Penicillium* spp. were the predominant fungi on seed that was treated and *Rhizopus* spp. on seed which was not. The source of the seed did not seem to affect the results obtained.

DISCUSSION

As indicated by the citations in the "Review of Literature" section of this paper, during the past decade a considerable number of agricultural research workers in North America and Europe have been interested in problems connected with storage of damp grain. On the whole, their published observations are in accord with those made during the present investigation.

A high water-content in grain appears to be the principal cause of its deterioration in storage. Dry grain does not spoil readily. Secondary causes of grain deterioration seem to be high temperature and poor aeration of storage, but they become important only when the water-content of the stored grain is high enough to allow microbial and enzymatic activity. The amount of mechanical injury to the grain appears to be a factor tertiary in importance. Its effect is governed by the impact of primary or secondary factors.

Reduced germinability in untreated damp grain seems to be due chiefly to the invasion of the kernels by mould fungi. Freshly-harvested grain is generally infected by a variety of fungi, of which the relatively harmless *Alternaria tenuis* is the most common one, and most of which also occur as air or soil contaminants. When the grain becomes damp through exposure to rain or snow, some of these grain-infecting fungi begin to grow luxuriantly while others are suppressed. The fungi most frequently found associated with mouldiness of grain have been species of *Mucor, Rhizopus, Aspergillus,* and *Penicillium.* In Western Canada, infection of damp grain by species of *Rhizopus* and *Penicillium* is much more common than infection by species of *Mucor* or *Aspergillus.* In the present investigation, *Rhizopus* developed mostly in stored untreated grain, and *Penicillium* in grain treated before storage with an organic mercury seed dressing. The predominance of *Penicillium* in treated grain is probably due to a high resistance of this group of fungi to the action of organic mercury compounds, rather than to a preference by these fungi for treated grain. It was found also that samples of damp grain from different localities tended to show different fungus floras at the beginning of storage, but these initial floras gradually became modified in the same direction during storage until eventually all the samples of grain were overgrown by the same fungi to about the same degree.

The water content affects the germination of treated grain also. Here the kind and amount of material used for seed treatment are the prime factors affecting the degree of injury to the treated grain (because some treatments cause no injury, while others cause a good deal) and the water content of the grain is less important because even dry grain tends to absorb fumes from volatile seed dressings. Nevertheless, treated damp grain suffers more chemical injury during storage than does treated dry grain and chemical injury is greater in closed storage than in well-aerated storage. Storage of treated grain at a high temperature harms it more than does storage at a low temperature. Wet grain, when dried well before treatment, does not suffer any more injury than does grain seed which had not been wet.

There has been some debate regarding the importance of treating moist grain. One worker (6) suggests that wet grain should be dried well before treatment, but if this is not possible the grain should be treated anyway. The treated wet grain should be sown shortly after treatment even when good storage facilities are available. Another worker (15) advises treatment of damp grain before storage, providing care is taken to avoid an overdose. It is suggested by the present writers that, unless the grain is contaminated by smut, treatment of moist grain may not be worth while. The reason for this is that when the grain is only moderately moist, its germination may be impaired by the treatment, and when the grain is very moist, the treatment seems to be ineffective in preventing deterioration.

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ERIOPHYID MITES IN RELATION TO THE SPREAD OF GRASS VIRUSES IN ONTARIO[1]

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ABSTRACT

Aceria tulipae (K.), *Abacarus hystrix* (Nal.) and *Vasates mckenziei* (K.) occur on wheat and *Agropyron repens* (L.) Beauv. naturally infected with Agropyron mosaic virus (AMV) in Ontario, but none of these mites has been proved a vector of this virus. *A. tulipae* from naturally diseased wheat caused a mild chlorotic mottle of wheat similar to mild strains of wheat spot mosaic from Alberta. Mites reared from eggs hatched on healthy wheat did not cause chlorotic symptoms on wheat. Wheat streak mosaic virus (WSMV) has not been found in Ontario, but *A. tulipae* from Ontario transmitted this virus as efficiently as a culture of *A. tulipae* from Alberta.

INTRODUCTION

Agropyron mosaic virus (AMV) (2, 3) occurs on wheat and *Agropyron repens* (L.) Beauv. in Ontario. It causes symptoms on wheat that resemble those caused by wheat streak mosaic virus (WSMV) which is transmitted by an eriophyid mite, *Aceria tulipae* (K.) (4). Like WSMV, AMV becomes prevalent on winter wheat that is sown in the spring and passes the summer and fall without maturing. The eriophyid mites *Aceria tulipae* (K.), *Abacarus hystrix* (Nal.) and *Vasates mckenziei* (K.)[3] are usually present on wheat and *A. repens* naturally infected with AMV; hence these mites were tested as possible vectors of the virus. Comparisons were also made between cultures of *A. tulipae* originating in Alberta and Ontario, as vectors of WSMV.

MATERIALS AND METHODS

In early tests Cornell winter wheat was used both as a host for AMV and eriophyid mites, but later, Kent wheat was used because it is as susceptible to AMV and mites and in addition is resistant to mildew. Wheat plants were used in the 1-2 leaf stage for mite-transmission tests, and in the 2-3 leaf stage for tests requiring sap transmission of the viruses. Methods for handling and caging mites on wheat have been described (4). Procedures used for different experiments are described below with each experiment.

EXPERIMENTS AND RESULTS

AMV Infection of Wheat Placed Near Naturally Diseased Agropyron repens

To test for natural spread of AMV to wheat, four pots of wheat seedlings in the 1-2 leaf stage were placed in a patch of naturally diseased *A. repens*. After 1 week the pots were removed to a greenhouse, examined for insects and mites, then sprayed with malathion and Kelthane to kill insects and mildew. The plants were kept for 4 weeks, during which time they were examined for mosaic symptoms. This test was repeated four times in June and July 1958, and each time several of the wheat plants developed symptoms of Agropyron mosaic. The presence of the virus in these plants was proved by sap transmission to other wheat plants. Eriophid mites were found on test plants in each test, but thrips and aphids were also usually present.

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[3]The mites were identified by H. H. Keifer, California Department of Agriculture, Sacramento, Calif.

Similar spread of AMV to wheat placed in close association with naturally diseased *A. repens* was demonstrated in the greenhouse. *A. repens* plants from the field were transplanted into four 8-inch clay pots, leaving a hole in the soil at the centre of each pot to accommodate a 4-inch pot in which Cornell wheat was planted. The small pots of wheat were replaced after 14 days. The numbers of infections occurring in six tests made in this way varied from none to as many as 6 out of 8 plants in a pot. The total infections from similar tests were 54 out of 224 test plants. Two species of eriophyid mites, *Abacarus hystrix* and *Vasates mckenziei*, were usually found both on the *A. repens* sources, and on the infected wheat, but attempts to transmit virus by transferring mites from the diseased wheat to other wheat seedlings failed.

AMV Spread from Naturally Diseased Wheat by Wind

It has been demonstrated that WSMV can be spread from naturally diseased plants by a fan because the vector, *Aceria tulipae*, is dispersed by wind (4). In an experiment repeated nine times, the airflow from an electric fan was directed across potted wheat plants naturally diseased with AMV, toward eight pots of healthy wheat test plants placed 2 to 4 feet behind the diseased plants. Two of the pots of test plants were covered with 10 cm.-x-25 cm. cylindrical plastic cages, the ventilator holes of which were covered with dacron taffeta cloth of such close weave that eriophyid mites could not enter. Two other pots had cages of sheer dacron, 72 mesh per inch, that excluded nearly all thrips. Two other pots were covered with cages of 52 mesh per inch colorless saran screen that excluded aphids but not thrips or mites. Two other pots were not covered with cages. The fan, blowing over the diseased and toward the healthy plants, was operated for 3 hours each afternoon. After 4 weeks' exposure to these conditions the plants were examined for symptoms of Agropyron mosaic. In three out of nine such tests symptoms developed on some of the test plants. The numbers of plants infected out of the total tested in the three successful tests were: 16/53 with no cages; 18/55 with 52-mesh saran screen cages; 18/55 with 72-mesh dacron cages, and 0/42 with mite-proof cages. One or more species of eriophyid mites occurred on all the plants that developed mosaic symptoms, but no mosaic infections occurred on wheat test plants to which they were transferred. Thrips were sometimes present on plants covered with 72-mesh cages. There was no correlation between the presence of aphids and the development of mosaic symptoms.

Tests for Transmission of AMV by Mites Transferred from Naturally Diseased Plants

To determine if the vector of AMV could be found on leaves of naturally infected wheat and *A. repens*, pieces of diseased leaves bearing mites, and sometimes also thrips, were placed on 6 to 8 wheat seedlings per pot and caged. In 12 out of 40 tests, several or all of the test plants in each pot became diseased with AMV. In 1 out of 6 tests, infection resulted when leaves of plants that had been infected by manual transmission were placed on test plants; hence it appears probable that some of the transmission from naturally infected leaf pieces may have resulted from rubbing, but the

rate of infection from naturally diseased leaves was higher than would be expected unless a vector was present. Thrips and aphids were sometimes present, but one or more of the three species of eriophyid mites, *A. tulipae*, *A. hystrix* and *V. mckenziei*, was always present when natural transmission occurred.

When mites found on naturally diseased wheat or *A. repens* were transferred individually, 10 to 15 mites to each of 6 to 8 test plants per pot, infection resulted in 3 out of 27 tests. Other tests were done in which the three species of eriophyid mites were transferred to separate groups of test plants. AMV was not transmitted in any of 38 tests with *A. tulipae*, 13 tests with *A. hystrix* or 7 tests with *V. mckenziei*. Thus, although natural transmission of AMV is associated with the presence of eriophyid mites, none of the recognized species has been proved a vector.

Chlorotic Mottle Caused by A. tulipae from Naturally Diseased Wheat

In some of the experiments for transmission of AMV, *A. tulipae* from naturally diseased wheat caused a faint chlorotic mottle on the wheat test plants. To test for a sap transmissible virus, sap from the chlorotic plants was rubbed on healthy wheat but no similar symptoms developed on the latter. Other viruses transmitted by *A. tulipae* are not transmitted through the eggs (4, 5). Tests were, therefore, made with mites reared from eggs found on diseased plants but hatched on healthy wheat seedlings grown in sterilized soil in large test-tubes. These mites did not cause chlorotic mottle. It therefore appears that these symptoms are probably caused by a virus carried by *A. tulipae* but not transmitted through the eggs, and not transmitted by manual sap inoculation. Spot mosaic, which is associated with wheat streak mosaic in Alberta, is caused by a similar virus transmitted by *A. tulipae* but it causes distinct chlorotic spots, and more severe chlorosis of plants (5).

Tests were made for synergism between chlorotic mottle transmitted by naturally infective *A. tulipae*, and sap-transmitted AMV and WSMV. Kent wheat was grown in 6-inch pots, 6 plants per pot. When in the 2-leaf stage the plants in three pots were inoculated with AMV, and in three others with WSMV. The plants in three other pots were not inoculated. Mites from plants with chlorotic mottle were transferred, 10 to each plant in one of the pots from each of the three series. Non-infective mites were placed

TABLE 1.—PER CENT CHLOROSIS OF WHEAT CAUSED BY CHLOROTIC MOTTLE VIRUS IN COMBINATION WITH AGROPYRON MOSAIC VIRUS AND WHEAT STREAK MOSAIC VIRUS.

Sap-transmitted virus	No mites	Non-infective *A. tulipae*	*A. tulipae* infected with chlorotic mottle
None	0[1]	0	10
AMV	10	10	30
WSMV	40	40	60

[1]Severity of chlorosis, recorded 6 weeks after the plants were infected, is based on estimates of reduction of chlorophyll in the plant leaves

on the plants in the second pot, and no mites on the third pot in each series. Six weeks later the severity of chlorosis caused by the various combinations of sap-transmitted viruses and mite infestations was estimated (Table 1).

All plants infested with mites had rolled leaves, a symptom caused by *A. tulipae* (4), but there was no evident chlorosis caused by the non-infective mites on any of the plants. All plants infested with mites from wheat with chlorotic mottle were 10 per cent to 20 per cent more chlorotic than their counterparts infested with non-infective mites, thus demonstrating a mild to moderate synergism between chlorotic mottle and the strains of AMV and WSMV tested. Mites from plants in the above experiment were transferred to other wheat plants to determine if both the chlorotic mottle and the sap transmissible viruses would be transmitted by the mites. AMV was not transmitted by *A. tulipae*, but WSMV was. Mites originating from cultures that were non-infective before being placed on plants infected with WSMV transmitted the latter virus. The test plants had 20 per cent chlorosis when results were recorded 4 weeks after the mites were placed on them. Mites reared on plants with chlorotic mottle, and then fed on plants inoculated with WSMV, caused 40 per cent chlorosis; hence they appeared to have transmitted both chlorotic mottle and WSMV.

Transmission of WSMV by Aceria tulipae from Ontario and Alberta

WSMV has not been found in Ontario, and although it was not transmitted by *Abacarus hystrix* or *Vasates mckenziei*, it proved readily transmitted by *Aceria tulipae* found on wheat in Ontario. It has been reported that *A. tulipae* from different sources may differ in efficiency of transmitting WSMV (1). Transmission tests were made to determine if *A. tulipae* from Ontario transmitted WSMV as efficiently as *A. tulipae* from Alberta. Non-infective mites were transferred to Kent wheat that had been infected with WSMV by sap inoculation. Three weeks later transmission tests were begun using single mites on single wheat seedlings grown in sterilized soil in 25 mm. x 200 mm. test-tubes. Transfers of mites were done with the aid of stereoscopic microscopes, and particular care was taken to ascertain that only one mite was deposited on each seedling. Transfers were done on five different occasions, and each time an equal number of Alberta and Ontario mites of each stage of development was tested, the numbers varying from 5 to 11, depending on the number of test plants ready. A total of 38 mites of each stage were tested. The stages of mites included 1st nymph, nymphs in the 1st moult, 2nd nymph, nymphs in the second moult, and adults. Egg transmission was also tested by placing 10 eggs on each of 5 wheat plants for each culture of mites. Two weeks after the mites had been placed on the plants, sulphur dust was blown into the tubes to kill the mites. Several days later the plants were transplanted into flats of soil. With the plants now growing uncovered, symptom development could be observed readily. As soon as unmistakable mosaic symptoms developed on a plant it was removed. The numbers of mites of each stage that transmitted WSMV to test plants are shown in Table 2. Mites transferred at all stages from 1st nymph to adult transmitted WSMV with about equal efficiency. Total transmissions were 57 per cent for mites from Ontario and 46 per cent for the mites from

TABLE 2.—COMPARISON OF WSMV TRANSMISSION BY INDIVIDUAL ACERIA TULIPAE FROM ONTARIO AND ALBERTA

Stage of mites when put on test plants	Number transmitting WSMV out of 38 tested	
	A. tulipae from Ontario	*A. tulipae* from Alberta
1st nymph	23	14
1st moult	24	18
2nd nymph	25	14
2nd moult	19	26
Adult	18	15
Per cent transmission by all stages	57	46

Alberta. It therefore appears that, although WSMV has not been found in Ontario, *A. tulipae* that occurs in Ontario is at least as capable of transmitting the virus as the culture of mites tested from Alberta.

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RELATIONSHIP BETWEEN CERTAIN METHODS AND PROCEDURES OF TESTING FOR WINTER INJURY OF OUTDOOR EXPOSED SHOOTS AND ROOTS OF APPLE TREES[1]

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ABSTRACT

Techniques of evaluating winter injury of apple shoots and roots were tested after the trees were exposed to natural outdoor freezing. The findings were compared with results of hardiness tests of similar trees following artificial freezing treatments previously reported.

Two-year-old apple trees of Northern Spy, McIntosh and Antonovka on *Malus robusta 5* rootstock were kept in pots outdoors during the winter of 1958-1959. The lowest air and soil temperatures recorded that winter were −26.0°F. and −1.0°F. respectively. Comparable control trees were kept in a storage cellar at a constant temperature of 32 ± 3°F.

An electrical resistance method was compared with two procedures for obtaining the electrical conductance of roots and of terminal, median and basal portions of twigs. A highly significant correlation existed between the conductivity and resistivity methods of testing. These methods and procedures are both sufficiently sensitive and consistent to warrant their use in studies of the effect of winter weather on various plant parts. However, the resistance method is preferable because it is much simpler.

The differences in the injury to the three varieties, to the three portions of the twigs, and following the two exposure treatments, were highly significant. Highly significant interactions were also found between varieties and treatments, between twig portions and treatments, and between varieties and twig parts. No significant differences were found between replications. The importance of these variances in terms of winter injury is discussed.

INTRODUCTION

Recent papers (7, 8, 9) have described several electrolytic methods and procedures for laboratory evaluation of artificially imposed freezing injuries of shoots and roots of apple trees. The object of this study was: 1) to determine the sensitivity and consistency of these techniques for studying the effect of actual winter weather on various plant parts; and 2) to estimate the degree of correlation between the aforementioned electrolytic evaluations. It was believed that the results of such a study would test the usefulness and increase the confidence in these methods of testing plants for winter hardiness. Such analyses would also assist in determining the relative importance of certain environmental and biological factors affecting winter injury of outdoor plants as well as the interactions between these factors.

MATERIALS AND METHODS

On November 19, 1958, six trees each of the apple varieties Northern Spy, McIntosh and Antonovka, all budded in 1956 on *Malus robusta 5* rootstocks, were brought indoors to a thermostatically-controlled storage room. The same number of trees of each variety was left outdoors in pots. Prior

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to November 19, all trees had been exposed to 17 days of outdoor cold hardening by light frosts ranging from 32°F. to 22°F. During the study, the storage room was maintained at a constant temperature of 32 ± 3°F., with artificial illumination of 32.8 watts per square foot, controlled with time-clocks to conform with natural daylight. Regulating indoor to outdoor daylength assured greater uniformity in the experimental material because evidence (4) showed that increasing the daylength may reduce the plant's ability to harden. The relative humidity in the storage room ranged from 90 to 100 per cent as compared with the relative humidity outdoors of 70 to 90 per cent. During the outdoor exposure, the mean air temperature was 10.6°F. with a minimum of –26.0°F., while the mean soil temperature in pots under an average snow cover of about 16 inches was 24.7°F. with a minimum of –1.0°F.

On March 9, 1959, both the shoots and roots of three of the six trees of each variety from storage cellar and from outdoor were tested for hardiness by two methods: (a) conductivity and (b) resistivity. These had been previously described (8) as two independent approaches for evaluating frost hardiness of fruit trees. The conductance of diffused electrolytes in water extract at room temperature was recorded in two ways: 1) in micromhos; and 2) as per cent of total conductance determined after boiling the tissues in water to release all the salts (9). The resistance of the diffused electrolytes *in situ* was determined in ohms with electrodes clamped directly into the plant tissues (8).

The remaining three trees of each variety, from both outdoor and storage room, were placed under the same outdoor growing conditions on April 16, 1959, to determine the varietal differences in their recovery and vigour during the following growing season. All dead portions of twigs were measured, and are expressed as per cent of total growth of branches for 1957 and 1959 inclusive. Representative trees were photographed on September 19, 1959 (Figure 1).

The data were analysed by standard statistical methods (2, 3, 6). As suggested by Snedecor (6) angular transformation of all percentage was made prior to the analysis. Because the three varieties were placed in their known order of hardiness (9) and the three twig portions in their known order of seasonal growth and development before the results of this study were known, no correction for "Students" t test was necessary (1, 5) in obtaining l.s.d. values.

EXPERIMENTAL RESULTS

The influence of exposure treatments on recovery and growth of the three varieties is shown in Figure 1. The generally retarded condition of the outdoor trees suggests that the varieties, especially Northern Spy, suffered a certain amount of winter injury to shoots and/or roots. Following outdoor exposure the Northern Spy, McIntosh and Antonovka trees had respectively 39, 12 and 5 per cent of injured twigs, whereas the indoor (check) plants had only 9, 6 and 0 per cent.

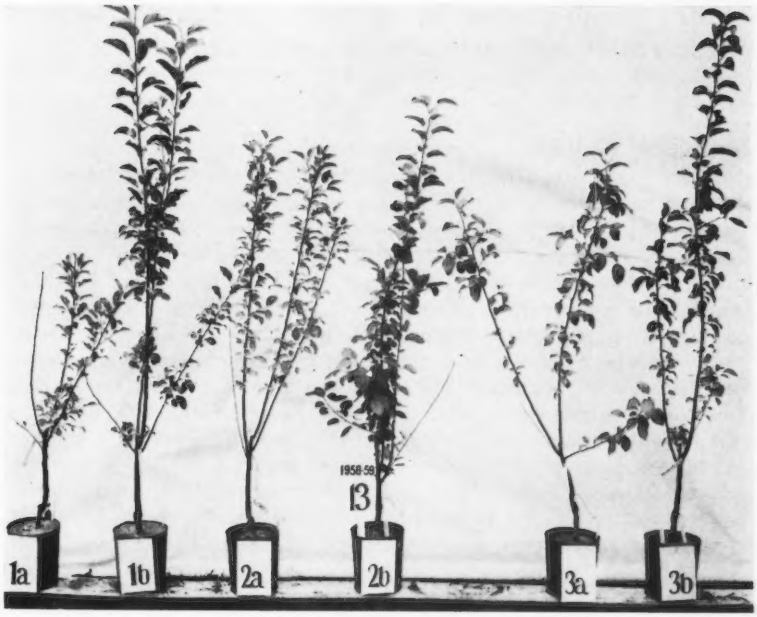

FIGURE 1. Differences in growth and development of apple trees: 1. Northern Spy, 2. McIntosh, 3. Antonovka, budded in 1956 on *M. robusta 5* rootstock, following *a.* outdoor exposure in winter of 1958-1959 and *b.* indoor storage. The findings of this study revealed that the retarded condition of the outdoor plants, especially the Northern Spy, was caused by winter injury to the roots as well as to the less mature terminal portions of shoots.

The data in Tables 1 and 2 show the electrolytic changes in the shoot and root tissues of the three apple varieties following the two types of exposures. The outdoor exposure compared with indoor treatment resulted in highly significant electrolytic changes of both shoots and roots. The conductivity and restivity methods of testing have both disclosed the electrolytic changes in the shoots of trees. In the roots the effects of exposures were also detected by the restivity method and by the conductivity procedures when the amount of diffusion was expressed as per cent of total conductance but not when expressed in micromhos. These findings on differences in the electrolytic methods and procedures for testing for frost injury of shoots and roots substantiate the results of a previous study (7).

Table 1 shows that, while there were no significant differences between the total conductance of the three varieties following exposure treatments, there were significant differences (1 per cent level) between their diffused portions. The much simpler resistivity method detected the differences in diffusion of electrolytes from the apple twigs as effectively as the conductivity method. Thus the resistance of the hardier Antonovka (36000 ohms) was significantly greater (1 per cent level), and its conductance (129 micromhos or 10 per cent of total) was significantly less (1 per cent level) than that of the more tender Northern Spy. In a previous study (9), following more severe artificial freezing, it was shown that the McIntosh variety was intermediate in winter hardiness to Northern Spy and Antonovka. In the present study such relative position was established only when the amount of diffusion was expressed in per cent of total conductance but not when expressed in micromhos as in the previous study, or by the resistivity method. The differences in the results of the two studies are mainly due to the differences in the nature of freezing exposures previous to the electrolytic tests rather than to the tests themselves. This is verified by the significant interaction between varieties and exposures as discussed later in this study. This also indicates the importance of suitable temperature treatments in tests, as adequate stress to plant tissues, to differentiate their varietal hardiness.

Table 1 also indicates that the average diffusion of electrolytes from the terminal portions of all twigs was significantly greater (1 per cent level) than from their median or their basal portions. The resistivity test confirms this, although only at the 5 per cent level of significance.

The highly significant interaction between varieties and exposures indicates that the three varieties responded differently to the exposure treatments. The more tender Northern Spy was influenced significantly more (1 per cent level) by the outdoor winter exposure (change in diffusion 14 to 26 per cent) than either of the other two varieties, while the reaction of the three varieties to the milder indoor treatments was about the same. The resistivity and conductivity methods established identical differences. This shows that the resistivity method, besides being much simpler, is just as effective in testing winter injury to trees.

The highly significant interaction between varieties and twig parts reveals that, in the tender Northern Spy variety, the terminal growth diffused significantly more (1 per cent level) electrolytes after exposure treatments

TABLE 1. — RESULTS OF ELECTROLYTIC TESTS TO DETERMINE CHANGES IN SHOOTS OF APPLE TREES DURING THE WINTER OF 1958-1959

Variety	Twig portion	Electrolytic tests and types of exposures											
		a. Conductivity									b. Resistivity (in ohms x 1000)		
		1. Diffusion (in micromhos)			2. Diffusion (per cent of total)			3. Total (in micromhos)					
		Out-door	In-door	Mean	Out-door	In-door	Mean	Out-door	In-door	Mean	Out-door	In-door	Mean
		Electrolytic readings, average of three replications											
Northern Spy	Terminal	390	403	396	27	16	21	1453	2470	1961	20	46	33
	Median	200	123	161	24	11	17	850	1160	1005	25	33	29
	Basal	197	120	158	28	14	21	717	907	812	22	28	25
	Mean	262	215	238	26	14	20	1006	1512	1259	22	36	29
McIntosh	Terminal	233	150	191	14	11	12	1697	1393	1545	29	35	32
	Median	163	120	141	16	14	15	1063	887	975	28	29	28
	Basal	150	127	138	19	15	17	773	850	811	30	31	30
	Mean	182	132	157	16	13	14	1177	1043	1110	29	32	30
Antonovka	Terminal	197	183	190	12	9	10	1573	2070	1821	24	45	34
	Median	113	83	98	10	8	9	1083	983	1033	41	37	39
	Basal	120	80	100	15	9	12	797	850	823	34	34	34
	Mean	143	115	129	12	9	10	1151	1301	1226	33	38	36
Average	Terminal	273	245	259	18	12	15	1574	1977	1775	24	42	33
	Median	159	109	134	17	11	14	998	1010	1004	31	33	32
	Basal	156	109	132	20	12	16	762	869	815	29	31	30
	Mean	196	154	175	18	12	15	1111	1285	1198	28	35	31

L.S.D. at the specified level of significance[1]	1. Diffusion (micromhos)		2. Diffusion (per cent of total)		3. Total (micromhos)		a. Conductivity		b. Resistivity (ohms x 1000)	
	5%	1%	5%	1%	5%	1%	5%	1%	5%	1%
Varieties (V)	33.3	44.7	1.6	2.1	—	—	2.6	3.4		
Exposures (E)	27.2	36.5	1.3	1.7	145.9	195.7	2.1	2.8		
Twig portions (T)	33.3	44.7	1.6	2.1	178.6	239.7	2.6	3.4		
V x E interaction	—	—	3.2	4.3	357.3	479.4	5.1	6.9		
V x T interaction	81.7	109.6	—	—	—	—	6.3	8.4		
E x T interaction	—	—	—	—	—	—	5.1	6.9		
V x E x T interaction	—	—	—	—	—	—	—	—		
Replications	—	—	—	—	—	—	—	—		
Error										
Total										

[1]The layout indicates the design of the experiment. The analysis of variance did not detect any significant differences where l.s.d. values are omitted.

than the median or basal parts (396, 161 and 158 micromhos, respectively) while the response of the three portions of twigs of the other two varieties was about the same. No such differential response to the exposure treatments was indicated by the more mature median and basal growth of the three varieties. The resistivity test also confirms this although at a lower level of significance than was shown by the conductivity method.

The resistivity test indicates a highly significant interaction between twig parts and exposures which was not shown by the conductivity techniques. The analysis of this interaction indicates that, averaging the three varieties, the terminal portions of twigs were influenced significantly more (1 per cent level) by the outdoor exposure (decline of 42000 to 24000 ohms) than were either of the other two portions. These results present further evidence that the resistivity technique may be regarded as a reliable method of testing the influence of winter exposure on the specified twig parts.

Studies were also made to determine the extent of association between the specified methods and procedures of testing for winter injury of woody plants. Correlation studies have shown that, following the outdoor exposure, there existed a highly significant negative association of $r = -.648$ for 25 d.f., between the conductivity in micromhos and resistivity in ohms of 27 portions of outdoor twigs (i.e. 3 varieties x 3 portions x 3 replications). This relation between the variates was verified by the highly significant negative regression coefficient of $t = -4.24$. The study also showed a highly significant negative correlation of $r = -.685$ between the conductivity in per cent and resistivity in ohms of the same over-wintered twigs, which was verified by the highly significant negative regression coefficient of $t = -4.70$. The above indicated associations were not found in the twigs of similar trees stored indoors. Highly significant positive coefficients of correlation of $r = .627$ and regression of $t = 4.03$ were established between the diffused portions of electrolytes of outdoor trees expressed in micromhos and in per cent.

Tables 1 and 2 did not indicate any significant differences between the three replicated trials used to test the efficiency of the several techniques for evaluating winter hardiness of shoots and roots of apple trees. This lack of variation between trials increases the confidence in the methods and techniques used to determine the several factors affecting winter injury of the fruit trees.

DISCUSSION AND CONCLUSION

This study proves the value of a relatively simple technique for testing and evaluating degrees of winter injury of woody plants and for determining the effects of certain biological and meteorological factors affecting such injuries. It is possible, by the simple procedure of clamping electrodes directly into tissues (8), to detect resistance changes in shoots and roots which occur during winter outdoor exposure and immediately predict the probability of their survival.

The electrical conductance of terminal, median and basal portions of twigs were compared with their electrical resistance. These are two independent electrolytic methods for evaluating hardiness of overwintering plants (8). The former determines in units of micromhos the extent of

TABLE 2. — RESULTS OF ELECTROLYTIC TESTS TO DETERMINE CHANGES IN *M. ROBUSTA* 5 ROOTS GROWN ON SPECIFIED VARIETIES OF SHOOTS DURING THE WINTER OF 1958-1959

Variety	Electrolytic tests and types of exposure											
	a. Conductivity									b. Resistivity (in ohms x 1000)		
	1. Diffusion (in micromhos)			2. Diffusion (per cent of total)			3. Total (in micromhos)					
	Out-door	In-door	Mean	Out-door	In-door	Mean	Out-door	In-door	Mean	Out-door	In-door	Mean
	Electrolytic readings, average of three replications											
Northern Spy	353	323	338	41	35	38	853	913	883	20	30	25
McIntosh	440	337	388	50	36	43	890	947	918	26	29	27
Antonovka	427	400	413	44	37	40	993	1073	1033	24	33	28
Mean	407	353	380	45	36	40	912	977	944	23	31	27
L.S.D. at the specified level of significance[1]	5%	1%		5%	1%		5%	1%		5%	1%	
Varieties (V)	—	—		—	—		—	—		—	—	
Exposures (E)	—	—		4.5	6.3		—	—		4.0	5.7	
V x E interaction	—	—		—	—		—	—		—	—	
Replications	—	—		—	—		—	—		—	—	
Error												
Total												

[1]The layout indicates the design of the experiment. The analysis of variance did not detect any significant differences where l.s.d. values are omitted.

diffusion of electrolytes from cells into water, while the latter establishes this *in situ* in units of ohms. Results reported here establish an existing correlation between the two methods of testing. Properly analysed quantitative ratings of hardiness of tissues expressed in ohms by the much simpler resistivity method gave as good results as the conductivity method in determining objectively the injurious effects on overwintered plants of some biological and meteorological factors as well as their interactions. In this manner it was found possible to establish some probable causes for the differences in the growth and development of apple trees after overwintering under the described outdoor conditions. Such winter conditions may also be considered typical for many other parts of Canada.

The findings of this study show that the methods used were sufficiently sensitive and consistent to establish that the retarded summer's growth of the apple trees (Figure 1) was due mainly to the influence of the preceding winter exposure. The three varieties responded differently to the prevailing winter conditions. The less hardy Northern Spy was injured proportionately more than the hardier McIntosh or Antonovka. Results demonstrated

that the outdoor condition, while fairly favourable to the survival of McIntosh and Antonovka trees, was too mild to confirm the relative differences in their frost hardiness which was established in a previous study (9). The methods used also established that, under the prevailing outdoor conditions, the less mature terminal growth of apples was injured proportionately more than the more mature median and basal portions of twigs. This confirmed previous findings on the importance of maturity in frost hardiness of overwintered shoots (9).

The *M. robusta 5* rootstocks, to which all varieties were budded, showed significantly higher conductivity (1 per cent level when expressed as per cent of total), or lower resistivity (1 per cent level), after outdoor exposure than after indoor storage. The hardiness of the roots, however, was not affected by the scion varieties.

The results of this study thus demonstrated the usefulness of relatively simple techniques for studying the complex phenomenon of frost hardiness. The methods used were reliable enough to determine the effects of commonly occurring winter weather, on hardiness of certain portions of shoots and roots of fruit trees. These tests should be of value in selecting hardy varieties of plants and in establishing proper cultural methods, if any, for overwintering such plants. The simplicity and practicality of the methods should encourage other workers at various stations to conduct research on hardiness problems on a much wider scale than attempted hereto. Utilization of all the information gained from such studies could benefit greatly the settled regions in Canada where winter injury is a common occurrence.

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ASTER YELLOWS RESISTANCE IN FLAX[1]

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ABSTRACT

A search for a source of resistance in flax to the virus disease called aster yellows was initiated in 1958. The variety Abyssinian (C.I. 302) from the World Collection of flax contributed a greater number of plants free from aster yellows symptoms than other varieties tested. Selection of plants free from symptoms after exposure to caged leafhoppers was carried out for five generations. A selected strain of Abyssinian was produced with a higher degree of aster yellows resistance. This strain is considered satisfactory as an aster yellows resistant parent in a breeding program.

INTRODUCTION

The virus disease aster yellows is found in many weeds, horticultural crops, ornamentals and some field crops such as flax and more recently has been reported in barley (1). The virus is transmitted by the six-spotted leafhopper, *Macrosteles fascifrons* (Stål.), which is widespread over the Prairies and which is usually blown northward in the spring from the southern United States (4).

In 1957 a severe epidemic of aster yellows on flax reduced the yield by an average of 15 per cent in Manitoba[5]. Similar reductions in yield were reported in Minnesota, North and South Dakota (2). Counts in plots growing at the Cereal Breeding Laboratory, Canada Department of Agriculture Research Station, Winnipeg, indicated no difference in the amount of infection on any commercially grown flax varieties or hundreds of hybrids. However, Frederiksen[6], working at the University of Minnesota, St. Paul, noted that 22 varieties growing in the World Collection of flax appeared to have less infection than the remainder.

MATERIALS AND METHODS

In order to commence a breeding program aimed at developing a variety of flax resistant to aster yellows, a search for a source of resistance was begun at the Cereal Breeding Laboratory in the spring of 1958. A logical starting-point appeared to be the less susceptible varieties in the World Collection (2). Accordingly, seed was obtained by the senior author from the U.S. Department of Agriculture, and a process of screening was initiated. Approximately 2,000 plants of each variety were sown, 10 seeds per pot, and grown in growth cabinets at 70°F. under 16 hours of fluorescent and incandescent light. Three weeks after planting, or when the plants were 4 to 5 inches high, individual cages were placed over each pot (Figure 1) and 20 to 25 six-spotted leafhoppers were released in each cage. These leafhoppers, 10 to 15 per cent of which were viruliferous, were allowed to feed on the flax plants for 5 days and were then destroyed by fumigation.

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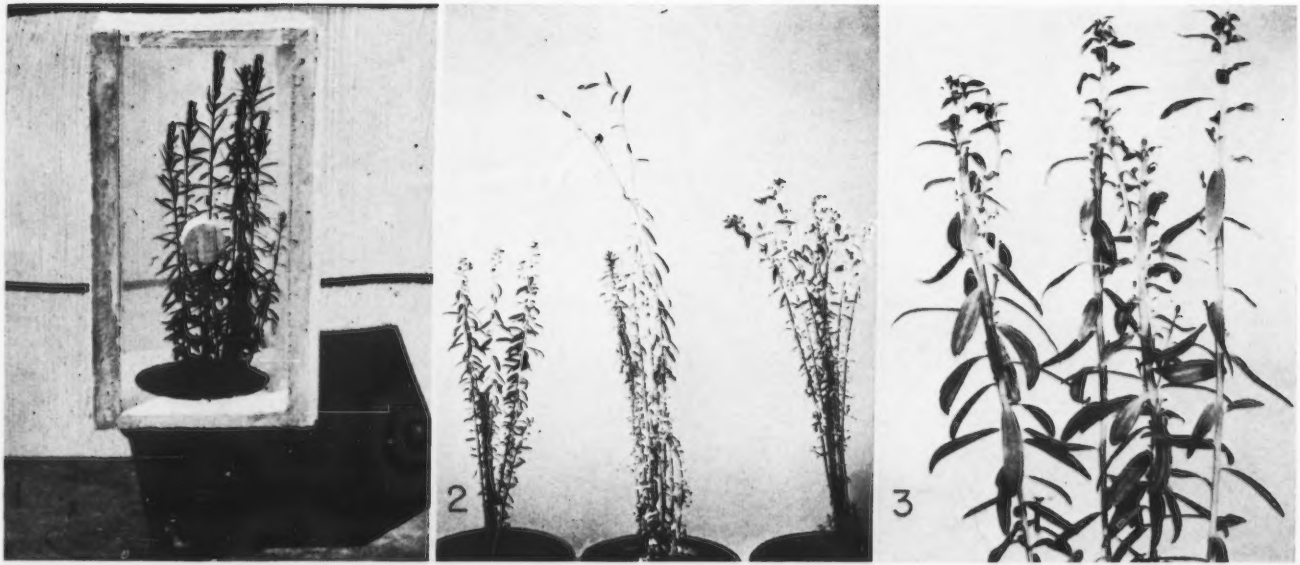

FIGURES 1-3: FIGURE 1. A single cage in place on a pot of growing flax plants.

FIGURE 2. All plants showing aster yellows symptoms with the exception of one plant growing in the centre pot.

FIGURE 3. Symptoms of aster yellows expressed when the plants were inoculated at an early age of growth.

RESULTS

Twenty to twenty-five days after inoculation, typical aster yellows symptoms appeared on most plants. Occasionally pots with one or two normal plants free of aster yellows symptoms were observed (Figure 2). Seed from such plants was harvested at maturity and furnished the basis for the next generation to be exposed to infection. Some plants whose emergence was delayed were younger when exposed to infection and had prebloom symptoms (Figure 3). Usually the upper portions of these plants were considerably thickened and bleached and the internodes were shortened, giving the plants a "clubbed" appearance. These plants were discarded.

The Abyssinian variety produced the greatest number of plants free from aster yellows symptoms, but 12 of the 22 varieties tested were almost completely susceptible and were discarded. The disease-free plants of the remaining 10 varieties were systematically harvested and the seed planted for five successive generations All 10 varieties continued to produce increasingly greater numbers of disease-free plants as the susceptible types were discarded through the rigid selection procedure. After the fifth generation, seed of the symptom-free plants of each variety was bulked for a final test in the field at Winnipeg. In addition, a portion of the bulked seed of each variety was tested at St. Paul, for a further check.

The varieties were planted in rod rows in the field at Winnipeg, with the commercial variety Bolley as the susceptible check. Three weeks after planting, large field-type cages were placed over each row and 75 to 100 leafhoppers, 15 per cent of which were viruliferous, were released in each cage. More insects per cage would have been desirable, but the supply was limited.

At maturity, all infected plants in each row as well as the total number of plants per row were counted. A considerable degree of late tillering occurred in all varieties following fall rains, and the incidence of aster yellows infection on the late tillers was high. The total number of plants per row, as well as the per cent infection, are presented in Table 1 as Test 1. The data presented as Test 2 were obtained at the University of Minnesota in a test where all varieties were replicated in three cages in the greenhouse and the leafhoppers were allowed to feed at random. In this test the unselected original varieties were used as checks. The data of Test 3 show the percentage infection where each variety was caged separately and the leafhoppers had no feeding choice. Again the check varieties were the unselected original lines.

In most tests, the strain selected from the Abyssinian variety was more resistant to aster yellows than either the selected strains of the other varieties or the checks. Bisbee indicated satisfactory resistance; however, its performance has been erratic in past tests. Therefore, it was considered unsuitable.

DISCUSSION

As far as is known, there is no report in the literature of aster yellows resistance in flax. The selected strain of Abyssinian appears to have sufficient resistance to aster yellows to give protection against the numbers of viruli-

TABLE 1.—PERCENTAGE OF ASTER YELLOWS INFECTION DETERMINED BY INOCULATION IN THE FIELD, WINNIPEG (TEST 1), AND IN THE GREENHOUSE, UNIVERSITY OF MINNESOTA (TESTS 2 AND 3)

Variety	C.I. no.	Test 1[1] Winnipeg, Man.		Test 2[2], St. Paul, Minn.				Test 3[3], St. Paul, Minn.			
				Selected		Unselected		Selected		Unselected	
		No. of plants	Infection %	No. of plants	Infection %	No. of plants	Infection %	No. of plants	Infection %	No. of plants	Infection %
Bolley		306	25	—	—	—	—	—	—	—	—
Abyssinian	302	113	16	20	15	16	56	20	0	16	25
Manchuria	303	94	49	19	53	20	35	19	42	19	26
Winona x Ott. 770B	674	93	32	19	21	19	32	20	15	14	36
Pinnacle	693	77	34	19	32	19	21	19	21	20	45
Atlas	1129	81	27	20	35	19	32	20	10	15	20
Ethendorf	1146	69	48	20	25	19	37	20	80	17	18
Argentine	1236	20	30	10	90	—	—	—	—	—	—
Argentine	1288	71	45	18	56	18	45	20	20	17	12
Turkey	1319	112	39	20	40	15	27	19	11	—	—
Bisbee	1336	230	24	20	10	14	43	—	—	16	31

[1]Leafhoppers 15% viruliferous; varieties caged separately (field)
[2]Leafhoppers 32% viruliferous; all varieties in one cage
[3]Leafhoppers 20% viruliferous; varieties caged separately

ferous six-spotted leafhoppers that could be expected during the growing season in Western Canada.

This strain, like its parental variety Abyssinian, is susceptible to rust, pasmo and wilt and is too short for growing on the Prairies. However, it would be satisfactory as an aster yellows-resistant parent in a breeding program.

The nature of the resistance in Abyssinian is not known. It is possible that a feeding preference is involved; but, when viruliferous leafhoppers were forced to feed on the selection, few or no symptoms of aster yellows were observed.

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THE SIX-SPOTTED LEAFHOPPER, *MACROSTELES FASCIFRONS* (STÅL.) AND ASTER YELLOWS IN MANITOBA

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ABSTRACT

The six-spotted leafhopper overwintered in the egg stage only. Adults migrated into Manitoba in substantial numbers on strong south winds in mid-May. The migrant population reached a peak of about 80 leafhoppers per 100 sweeps in mid-June on cereals. There was a high mortality of migrants in late June and early July. The non-migrant population originated partly from overwintered eggs but mostly from eggs laid by migrants. New generation adults appeared in late June. Distinct broods were not apparent in the field because generations overlapped. The peak of population, about 400 leafhoppers per 100 sweeps, was reached about mid-August. Four generations were reared in a year. In general field collections the percentage of leafhoppers transmitting the aster yellow virus did not exceed 1 per cent. The percentage transmission was highest in the migrant population but dropped in July and August with the increase in local population. The rate of virus transmission was low in June and July but reached a peak in August in conjunction with the peak in population. Some weeds are a source of aster yellows virus. In Manitoba, early maturing crops generally escape severe aster yellows infection but it is often a problem on late crops.

INTRODUCTION

The six-spotted leafhopper, *Macrosteles fascifrons* (Stål.) and its relationship to the aster yellow virus, *Chlorogenus callistephi* H., has been studied extensively in North America and thoroughly reviewed by Chapman (2) and Chiykowski (4). Lee and Robinson (10) and Sackston (15, 16) have reviewed the importance of the insect and disease in Manitoba. This paper is a report of work conducted at Winnipeg, Manitoba, from 1958 to 1960 on the biology of the insect and on the occurrence of the virus.

BIOLOGY OF THE INSECT

Overwintering

In Manitoba, adult six-spotted leafhoppers usually appear in small numbers about mid-May. These have generally been considered as overwintered specimens. From 1954 to 1957, inclusive, the earliest occurrence ranged from May 6 to May 29 (10). In 1958, 1959 and 1960 they were first taken near mid-May. Tests, as follows, were conducted to determine whether or not the six-spotted leafhopper overwintered in any stage in Manitoba.

Nymphs and adults – The winter of 1957-58 was mild with little or no snow cover. In February, 1958, ten square-foot samples of plant debris and soil, to a depth of 2 to 3 inches, were taken from each of: an open field, a shelter-belt, the south slope of a road embankment, and the southern edge of a grove in an area on the University of Manitoba campus where there had been an extremely high leafhopper population in 1957. The samples were held in 32-mesh saran screen cages in the laboratory at 70-75°F. for 2 weeks. No adults of the six-spotted leafhopper emerged.

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The winter of 1958-59 was relatively severe but with heavy snow cover. In the fall, the air temperature seldom went below freezing and leafhoppers were active on warm days until a heavy snowfall on November 18. At intervals during the winter, samples of soil and fall rye plants, (*Secale cereale* L.) were removed to the laboratory from a field in which leafhopper nymphs and adults were present in extremely large numbers until the heavy snowfall. The samples were held in 32-mesh saran screen cages at 70-75°F. for 1 week. No nymphs or adults emerged. Cages, of 32-mesh saran screen, 15 by 1.5 by 1.5 feet, set over rows of a very heavy growth of fall rye on November 12, 1958, and stocked with 1500 adult leafhoppers each, did not yield live adults in the spring.

In 1958 and 1959, intensive sweeping and field observations on fall rye, grasses and weeds in sunny exposures on warm days, during April and early May revealed no six-spotted leafhoppers. It is concluded that the six-spotted leafhopper does not overwinter as a nymph or adult in Manitoba.

Severin (18) reported that the adult overwintered in California and according to Chapman* it remains active throughout the winter in the winter vegetable areas of southwestern Texas and probably in southern New Mexico, Arizona and Florida.

Egg — To determine if overwintering occurred in the egg stage, rye in pots and flats was exposed to leafhoppers, in cages in the laboratory, in the fall of 1958 and 1959, and subsequently placed in the field. At intervals from November to March each year, pots and flats were brought into the laboratory and immediately caged to prevent contamination. On each occasion first instar nymphs were noted on the plants after an incubation period of about 10 days. This was the first direct evidence that the six-spotted leafhopper was able to overwinter in the egg stage in Manitoba.

In April of 1959 and 1960 samples of a number of plant species were removed from the field and caged in a greenhouse at approximately 75°F. Each sample consisted of 30 feet of row of rye or its approximate equivalent of other plant species. After 3 weeks the number of nymphs per cage was recorded. In 1959 the mean emergence of nymphs from two light stands of fall rye at Carberry, Manitoba, was 2 per lineal foot of row; for heavy stands of fall rye at Winnipeg, the mean was 9.5. There was no emergence of nymphs from fall rye from two fields near Morden; nor was there any emergence from samples of: a mixture of brome (*Bromus* sp.) and bluegrass (*Poa* spp.), dandelion (*Taraxacum officinale* Weber), dragon head (*Dracocephalum* sp.), dock (*Rumex crispus* L.), stinkweed (*Thlaspi arvense* L.) and grass from sloughs taken at Winnipeg and other areas of the province. In 1960, the mean emergence of nymphs from good stands of fall rye at Winnipeg ranged from 4 to 21 per lineal foot of row; for light stands of fall rye in western Manitoba the mean was 0.5. In wild barley (*Hordeum jubatum* L.) the mean emergence was 0.5 nymphs per foot of row and for each of stinkweed and dandelion the mean was 0.1 nymphs per foot of row. No nymphs emerged from samples of clover (*Trifolium repens* L.) or straw-

*Chapman, R. K., University of Wisconsin, Madison, Wis. *Personal communication.*

berry (*Fragaria* sp.). Fall rye appears to be a good overwintering host, and in Manitoba is one of the few succulent plants in abundance in the fall.

Migration

In 1958 and 1959 adults migrated into Manitoba in substantial numbers on strong south winds about mid-May. In 1958 extensive and intensive sweeping on various crops and weeds yielded no nymphs or adults of the six-spotted leafhopper prior to May 12. On May 12 and 13 there were continuous strong south winds, averaging 29.8 m.p.h., with gusts up to 70 m.p.h., accompanied by temperatures up to 89°F. for a period of 20 hours. On May 13 the six-spotted leafhopper was collected from several crops at Winnipeg. Leafhoppers were first taken at Saskatoon on May 12* and near Edmonton when collections were made on May 24, 1958. In a single day leafhoppers were carried from south of Manitoba as far north and west as Winnipeg and Saskatoon and probably as far as Edmonton.

Further evidence of migration is provided in another report by Brooks*. He stated:

> "In Moose Mt. area [Saskatchewan] from Whitewood to Oxbow but chiefly in bush around Kenosee and Carlyle, *Macrosteles* very abundant in all habitats from bare hillsides to dense bush but especially in grassy slough bottoms surrounded by bush—population on June 11 (Kenosee) in one slough bottom 5000-6000 per 25 sweeps (5 o'clock p.m.). General population ¼ to ½ this amount but very variable depending on time of day, temperature, etc."

This is an extremely high population and it is important to note that it was made up entirely of adults. If it may be assumed that these were not overwintered specimens then they must have moved into the area from some distance. Had they originated from overwintered eggs, nymphs would almost certainly have been present in collections made so early in the season. The attraction of the six-spotted leafhopper to the moist grassy slough bottoms agrees with observations made by Freitag (5) in California.

In 1959 no leafhoppers were collected in Manitoba until after strong south winds of several hours' duration on May 9 and 10. Although this remarkable type of migration has occurred in two successive years, a study of mass airflows as reported by Chiykowski (4) indicates that normally leafhopper migration would be somewhat less abrupt, occurring more gradually, and over a longer period.

Abundance and Seasonal Life History

To determine the leafhopper population in 1958 and 1959 several fields near Winnipeg were swept twice per week, weather permitting, from late May until harvest. The crops swept in 1958 were fall rye, early oats, late oats, flax, sunflowers and green feed (oats and millet). In 1959 sweeps were made on fall rye, wheat, barley, oats, flax, carrots, lettuce, stinkweed and miscellaneous plants and weeds. Usually 250 sweeps, with a 15-inch net, were made in each field. A sweep was a single stroke of the net over a distance of approximately 3 feet. To maintain uniformity all sweeps were made by the same individual. The number of nymphs and adults collected was recorded. Variations in temperature, precipitation, wind velocity,

*Brooks, A. R., Can. Dept. Agr. Research Sta., Saskatoon, Sask. *Personal communication.*

cloudiness or relative humidity affected the number of leafhoppers collected. Usually the greatest number of leafhoppers per sweep was collected from late afternoon to dusk, when the air was still, warm and humid.

Migrants — In both 1958 and 1959 few leafhoppers were found until about mid-June when there was a peak of about 80 leafhoppers per 100 sweeps on cereals (Figures 1 and 2). The apparent increase in numbers in June is due partly to a movement of leafhoppers to preferred foods. Lee and Robinson (10) showed that the six-spotted leafhopper preferred lettuce over several other plant species for feeding and oviposition. The mean number of leafhoppers, per 100 sweeps for three replicates in 1959 and per 50 sweeps for five replicates in 1960, on various crops was as follows:

	June 1, 1959		May 20, 1960		May 25, 1960	
	No.	S. E.	No.	S. E.	No.	S. E.
Bluegrass	0.0	—	0.0	—	0.0	—
Brome	0.0	—	1.4	0.13	0.6	0.21
Wheat	6.0	3.33	—	—	—	—
Barley	25.0	2.84	—	—	—	—
Fall rye	—	—	22.4	2.54	47.6	5.03

Observations have shown that cereals are among the favoured foods of leafhoppers and among cereals barley is preferred. Hervey and Schroeder (6) showed the order of feeding preference to be barley, rye, wheat and grass.

Movement of leafhoppers from one crop to another has been observed in the field, particularly in spring. In late June movement from ripening plants such as rye and stinkweed was reflected in larger collections on more succulent crops such as flax and oats (Figures 1 and 2). Further evidence of local movement of leafhoppers was seen later in 1958 in the extremely high population in the field of late oats and millet (Figure 1). Very few nymphs developed in this late crop and the high population was due almost entirely to an influx of leafhoppers from ripening grains. Osborne (13) noted that "the adults fly readily and probably to considerable distance . . ." According to Hervey and Schroeder (6) local migration occurs when grain has approached maturity and is no longer suitable for food. Since there is no apparent breeding of the six-spotted leafhopper on potato, Leach and Bishop (9) concluded that the leafhoppers on potato had migrated from other hosts.

The apparent increase in numbers in June could also have been due to continued migration of leafhoppers into Manitoba. According to Chapman (3) leafhoppers do not fly at temperatures below 60°F. In Manitoba, in May and early June, temperatures as high as this are usually associated

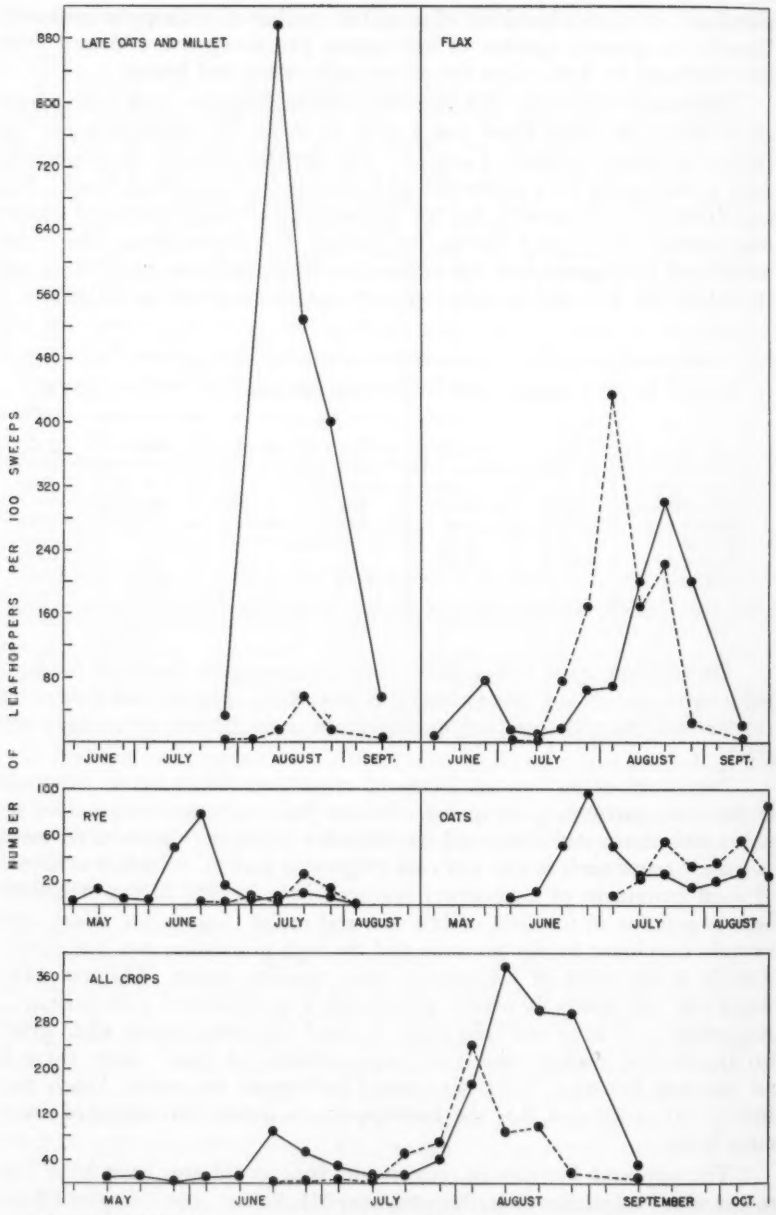

FIGURE 1. Abundance of the six-spotted leafhopper in various field crops near Winnipeg, Man., 1958, based on 250 sweeps, twice each week, in one field of each crop. (*Solid line*–adults: *broken line*–nymphs).

with south winds. Meteorological data for May 15 to June 15 show that south winds at temperatures of 60°F. or higher occurred as follows:

Date	Duration (hours)	Velocity, m.p.h.	
		Range	Average
1958			
May 16-17	5	16 to 17	16.4
May 25-26	8	15 to 26	21.5
May 28	3	10 to 14	11.6
June 2	5	21 to 28	24.5
June 8-9	20	6 to 26	16.6
1959			
May 24-25	16	13 to 32	23.1
May 30	4	9 to 13	11.8
June 1	4	9 to 17	14.2
June 5-7	13	2 to 23	16.2
June 9-10	14	3 to 26	16.2
June 13-14	10	15 to 23	18.4

Leafhoppers could have moved into Manitoba on these winds. However, once the first migrants have arrived the detection of subsequent arrivals is virtually impossible. Any substantial influx of leafhoppers beyond mid-June is unlikely in view of the marked decline in population after June 15 (Figures 1 and 2).

The marked drop in population in late June and early July (Figures 1 and 2) appears to be due to high mortality of migrants. The mortality is probably even greater than that indicated by the curves since local first generation adults begin to appear in late June and bolster the declining population.

In 1959, 200 migrant leafhoppers collected on June 9 and caged in the greenhouse died by July 4.

Non-migrants – The local six-spotted leafhopper population originates partly from overwintered eggs but there is strong evidence that it originates mostly from eggs laid by migrants. In 1958 and 1959 nymphs appeared earlier in fall rye than in spring crops but were fewer in fall rye (Figures 1 and 2). Moreover, the overwhelming preponderance of the spring crop acreage in Manitoba over that of fall rye suggests that most of the leafhopper population must come from increase on spring crops.

To determine the number of generations, leafhoppers were reared in cages in the field. The first fifth-instar nymphs collected in spring were caged. When new adults appeared, about 100 were placed on pre-caged barley for 24 hours. The cage was then removed, the barley sprayed with tetraethylpyrophosphate to destroy adults and the cage replaced. Thereafter, when new adults appeared in the cage they were removed and placed in a new cage and the same procedure repeated.

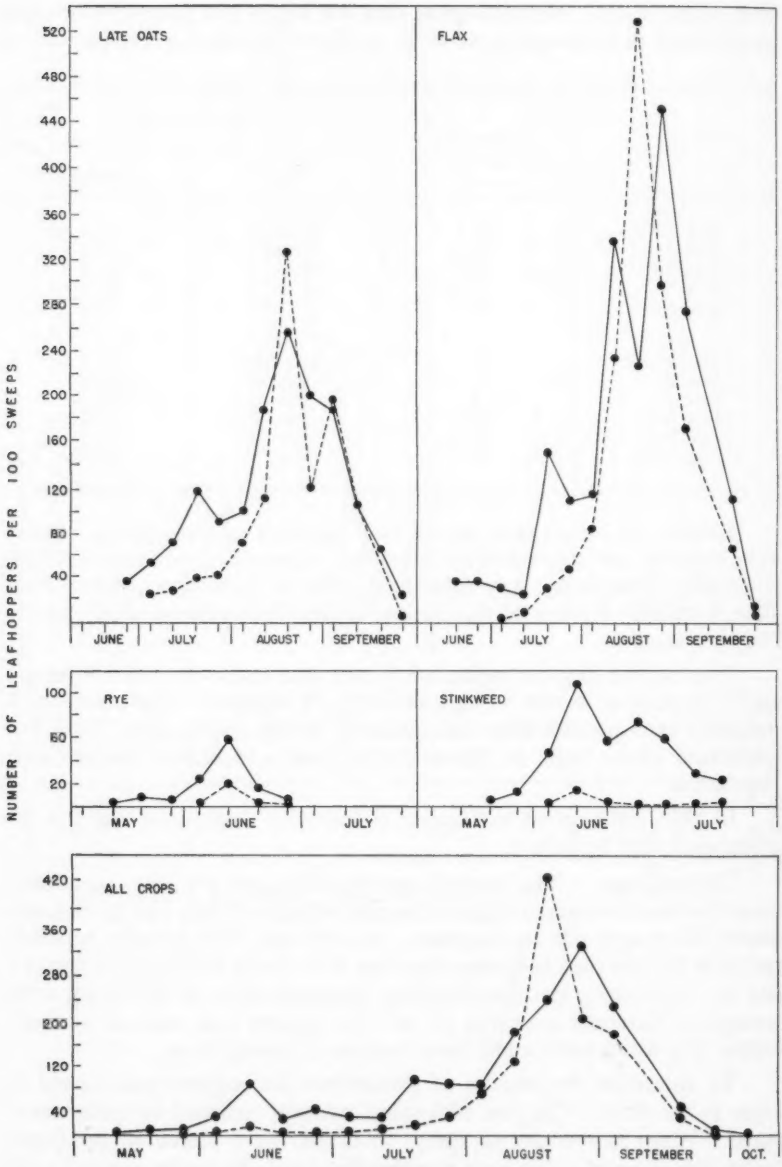

FIGURE 2. Abundance of the six-spotted leafhopper in various field crops near Winnipeg, Man., 1959, based on 250 sweeps, twice each week, in one field of each crop. (*Solid line*—adults: *broken line*—nymphs).

In 1958, fifth-instar nymphs were first collected from the field on June 26 and new generation adults were present by the end of the month. In the cages a second generation was reared by August 1 and a third by September 1. No further rearing was attempted. Leafhoppers were active on warm days in sunny exposures as late as November 12, indicating that a fourth generation probably could have been reared.

In 1959 nymphs began to appear in late May and first generation adults were present in late June. In the cages second-generation adults were present on July 27, third-generation adults on September 2 and fourth-generation adults on October 5. In the second generation, nymphs appeared after 16 days. Nymphal development was completed in 21 days.

Distinct broods are not apparent in the field because of the overlapping of generations. This results in one large peak of population (Figures 1 and 2). On this basis Lee and Robinson (10) indicated only one generation per year in Manitoba. Osborne (14) found that in Maine there were probably three complete broods each year, and each required about 27 days from egg to adult.

OCCURRENCE OF THE VIRUS

Percentage of Leafhoppers Transmitting Virus

In 1958 and 1959 leafhoppers were collected at intervals from various crops and caged on asters to determine the percentage of leafhoppers transmitting the aster yellows virus at different times of the year. The periods of greatest interest were: *Spring* — when only migrant leafhoppers were present; *July* — the period of low numbers when migrants were dying and new generation adults were appearing; and *August* — when the locally developed population was at its peak.

The leafhoppers were caged singly or in groups of 3 or 5 in "clip" cages, similar to those described by MacGillivray and Anderson (11), on individual aster plants of the variety Powder Puff. The cage was a cellulose nitrate cylinder, 1 inch high by ½ inch in diameter, covered at the top with 54-mesh nylon screen, and at the bottom with a cellulose nitrate disk with a quarter-inch hole covered with 54-gauge 15-denier nylon cloth. A hole in the side of the cylinder, for introducing and removing leafhoppers, was fitted with a 000 stopper. A hair-curl clip was fitted to the bottom of the cage to provide a means of attaching the cage snugly to the surface of the aster leaf. The leafhoppers fed through the nylon over the hole in the bottom of the cage.

Leafhoppers collected in the field were placed in a large cage from which they were aspirated at random and placed in the clip cages, singly and in colonies of 3 and 5 per cage. They were held on the plants for 48 hours. After exposure the plants were held for 6 weeks for symptom expression.

The frequency of transmission was low (Table 1). Of 1500 leafhoppers tested singly on asters, 9 were viruliferous, giving a frequency of transmission of 0.006. Based on this frequency of transmission, where

TABLE 1.—PERCENTAGES OF LEAFHOPPERS TRANSMITTING VIRUS IN COLLECTIONS FROM FIELD CROPS[1] 1958 AND 1959

Period	Number of leafhoppers tested	Number of plants infected	Per cent[2] leafhoppers transmitting
1958			
June 1-30	681	6	0.88
July 1-31	832	3	0.36
Aug. 1-31	1160	2	0.17
Total	2673	11	
Average			0.41
1959			
May 15-June 30	2286	16	0.70
July 1-31	1755	10	0.57
Aug. 1-31	867	3	0.35
Total	4909	29	
Average			0.59

[1]Cereals, flax, sunflowers
[2]Based on calculated probability that each transmission resulted from a single leafhopper, even when tested in colonies of 3 or 5 per plant

colonies of 3 leafhoppers per plant were tested, the probability of none being viruliferous is 0.982; of one being viruliferous, 0.018; of 2 being viruliferous, 107×10^{-6}; and of all 3 being viruliferous, 216×10^{-9}. Where colonies of 5 leafhoppers per plant were tested, and based on the same frequency of transmission, the probability of 4 or 5 leafhoppers in the colony being viruliferous becomes infinitesimal. Because of this low frequency of transmission each transmission is assumed to have resulted from a single leafhopper.

In 1958 and 1959 the percentage of leafhoppers transmitting virus in general field collections (exclusive of collections on weeds and lettuce) did not exceed 1 per cent (Table 1). It was highest in the migrant population and dropped in July and August, particularly in 1958. Viruliferous leafhoppers do not always transmit each day as the data of Maramorosch (12) show. Kunkel (8) showed this inconsistency in transmission and reported that leafhoppers, transferred to new aster plants daily, transmitted virus to about three-quarters of all the plants on which they fed after becoming infective. This would suggest a somewhat higher percentage of infected leafhoppers than that indicated in Table 1.

It should be noted that migrant leafhoppers, tested in the latter part of June, could have become infective after arrival in Manitoba, since sufficient time had elapsed for incubation of virus acquired before migration or even virus that might have been acquired locally. Although virus transmission dropped somewhat in August there were many more viruliferous individuals in August than earlier in the season because of the large numbers of leafhoppers present.

Sources of Virus

The presence of viruliferous leafhoppers in the locally developed population presupposes a local source of virus. Leafhoppers were collected from various crops and caged on asters. The results of transmission tests from July 1 to September 30 in 1958 and 1959 were as follows:

	Number of leafhoppers tested	Host	Viruliferous leafhoppers	
			Number	Per cent
1958	1500	Lettuce	18	1.2
	1833	Other crops	4	0.2
1959	665	Lettuce	10	1.5
	539	Stinkweed and prickly lettuce	6	1.1
	2978	Other crops	6	0.2

Garden lettuce is susceptible to the virus, has a short incubation period for the virus, and is a preferred breeding and feeding host. Leafhoppers collected from lettuce would, therefore, be expected to have a higher proportion of viruliferous individuals than those collected from crops that are less susceptible to the virus or less attractive to the leafhopper. Most of the leafhoppers collected from other crops in 1958 and 1959 were from cereals, with some collections from flax and sunflowers. Cereals, except for Vantage barley which has recently been reported as a host of the aster yellows virus by Banttari and Moore (1), have long been considered immune to the virus; flax is susceptible but leafhoppers do not readily acquire it from the plant (17); sunflowers are not highly susceptible and require a long time for virus incubation. As shown there was a low frequency of transmission from leafhoppers collected on these crops. Stinkweed and prickly lettuce (*Lactuca scariola* L.) are susceptible, relatively attractive to the leafhopper, and as shown in collections from these plants a relatively high percentage of leafhoppers transmitted the virus. These weeds, particularly stinkweed, are very common in Manitoba and could be an important source of virus. Virus symptoms were also common on flixweed (*Descurainia sophia* (L.) Webb) and ground sel (*Senecio vulgaris* L.), but diseased plantain (*Plantago major* L.), and dandelion were difficult to find.

Rate of Virus Transmission in the Field

To determine the rate of virus transmission, in 1959, a hundred aster plants were placed in the field on the 1st and 16th day of June, July and August and on September 1. At the end of each half-month period the plants were removed to the greenhouse and held for virus symptom expression. In addition, at approximately the same intervals from mid-July

to mid-September, the number of infected plants in a field plot of carrots was recorded. The percentages of plants infected were as follows:

	June	July		August		September
	15-30	1-15	16-31	1-15	16-31	1-15
Aster	3	4	3	29	20	8
Carrot	—	—	2.1	4.3	10.4	16.5

The rate of transmission was very low in June and July. However, the combination of large numbers of leafhoppers in August with a relatively high percentage of viruliferous specimens in that population resulted in a peak rate of transmission of the virus in August.

In the fall of 1959, ripe and green flax fields were examined to determine the percentages of plants infected by aster yellows. Two samples of 500 feet of row each, or about 18,000 plants per field, were examined. The mean percentages of infected plants for 19 ripe fields and 19 green fields were 0.15 and 0.74, respectively. An analysis of variance showed the difference in percentage infection to be significant at the 1 per cent level. This supports the evidence of a higher rate of virus transmission late in the season.

Because the rate of virus transmission in Manitoba is highest in August, aster yellows is normally not a serious problem on relatively early maturing crops. For this reason, Manitoba growers are able to produce a crop of lettuce from early transplants with little or no aster yellows. Only under conditions such as in 1953 and 1954 and 1957, when leafhoppers were present in very large numbers or a high percentage of the migrant population was viruliferous, would such crops be severely infected (19, 20, 17). However, each year the disease is a serious problem on field-sown lettuce and carrots and a potential threat to other late crops.

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THE INFLUENCE OF HONEYBEE POLLINATION ON FRUIT SET OF THE LOWBUSH BLUEBERRY[1]

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ABSTRACT

Inconsistent results were obtained when the fruit set was determined in blueberry fields with and without the service of honeybees. Adverse weather conditions curtailed pollinator activity and this was reflected in poor fruit set. The advantage of using honeybees was more evident in the season which had a short period of bloom. No significant increase in percentage fruit set was obtained when the number of colonies of honeybees per acre was increased. There was also no correlation between percentage fruit set and composition of plant stand.

INTRODUCTION

The importance of honeybees as a supplement to native bees in the pollination of lowbush blueberry has not been clearly established. Several workers have observed that native bees are not particularly abundant in blueberry fields during the period of bloom, and have suggested that fruit set may be increased substantially by the use of honeybees. In his work with caged honeybees Lee (4) concluded that the lowbush blueberry is capable of setting and maturing fruit on a high percentage of its flowers, and that the honeybee is an effective pollinator of this plant. Karmo (3) has reported promising results from the use of honeybees in blueberry pollination in Nova Scotia.

Preliminary investigations in New Brunswick showed that blueberry blossoms must be insect pollinated before they can set fruit. In this area pollination is performed almost entirely by bumble bees and solitary bees. While many clones of blueberry have been noted with fruit set in excess of 70 per cent, the average set on a field basis is rarely over 50 per cent and is generally considerably lower. Since populations of native bees may fluctuate considerably from year to year and are never as plentiful as one might desire, the most promising approach towards increasing the percentage fruit set would seem to be in the use of honeybees.

This paper presents the results of studies on blueberry pollination in New Brunswick in 1957, 1958, and 1959. Data are presented on fruit set in fields with and without honeybees, and in fields with honeybees supplied at the rate of one, two, and three colonies per acre. The influence of weather on pollination is discussed briefly.

In New Brunswick there are three recognized lowbush blueberries; *Vaccinium myrtilloides* Michx. is a diploid, and *V. angustifolium* var. *laevifolium* House and *V. angustifolium* var. *nigrum* (Wood) Dole are tetraploids (1). Of these *V. angustifolium* var. *laevifolium* is the predominant species, particularly in stands which have been developed from abandoned hayfields (2). It seemed advantageous to investigate the relation of fruit set to plant stand concurrent with the study of honeybee influence, and the results of this investigation are, therefore, included in this paper.

[1]Contribution No. 39, Research Station, Canada Department of Agriculture, Fredericton, N.B.

MATERIALS AND METHODS

The study was made in the vicinity of Tower Hill, Charlotte County, New Brunswick. First crop fields only were selected. Honeybees were placed in one group of fields when the plants were coming into bloom and the check fields were left to be pollinated by native bees. Honeybees were purposely placed in those fields which had the greater amount of isolation from the bloom of competitive plants and from other blueberry fields, hoping thereby to induce the honeybees to work the blueberries more thoroughly. The fields containing honeybees were also far enough from each other and from the control fields that spill-over of bees from one field to another was negligible. In 1957 and 1958 one, two, and three colonies per acre were used, whereas in 1959 only one colony per acre was used.

The percentage fruit set in each field was obtained from counts of blossoms and berries in 25 one foot-square plots located at random. In the fields with honeybees the plots were contained within a 2-acre area about the hive site. Stand composition in the various fields was determined by recording the species of blueberry occurring at 1-yard intervals on a 100-yard line transect selected at random five times in each field.

RESULTS

Observations on the percentages of fruit set (Table 1) showed that in 1957 and 1958 there was no significant difference in the proportion of flowers which set fruit in the fields with or without honeybees. In 1959, however, the introduction of honeybees more than doubled the proportion of flowers which set fruit, as compared to those which were accessible to native bees only. This difference was highly significant.

There was no significant increase in set when the number of colonies per acre was increased (Table 2). It should be pointed out, however, that the number of colonies used may not be a good criterion for density of bees in a field. In the Tower Hill area most blueberry fields are less than 10 acres in area, and are either contiguous with or very close to other blueberry fields. Under such conditions honeybees rapidly extend their foraging range, and the density of bees in a given field does not increase in proportion to the number of colonies used unless all growers in the immediate area also use honeybees.

TABLE 1.—PERCENTAGES OF FRUIT SET IN BLUEBERRY FIELDS WITH AND WITHOUT THE EMPLOYMENT OF HONEYBEES

Year	Bloom period	Fruit set with honeybees			Fruit set without honeybees			Difference	P
		N	$\bar{X}$	S.E. % $\bar{X}$	N	$\bar{X}$	S.E. % $\bar{X}$		
1957	May 15-June 7	7	37.6	6.7	7	36.1	6.5	+1.5	0.70
1958	May 22-June 6	6	18.1	20.4	10	24.2	5.8	−6.1	0.10
1959	May 22-May 30	5	52.8	5.7	5	23.8	8.4	+19.0	0.001

TABLE 2.—PERCENTAGE OF FRUIT SET IN RELATION TO DENSITY OF HONEYBEES

Year	Density of honeybees (colonies/acre)			F
	1	2	3	
1957	49.6 39.0 38.2	41.4 31.8	32.4 31.1	2.13 N.S.
1958	18.7 17.2	17.4 12.9	27.6 20.9	3.87 N.S.

A survey of all fields in which records on fruit set were taken during the 3-year study on honeybees showed no correlation between fruit set and composition of stand. Forty-two fields were sampled and the coverage by tetraploid species ranged from 97.2 to 4.1 per cent. Most fields contained between 50 and 70 per cent tetraploids. An analysis of covariance was made on fruit set and percentage coverage by *V. angustifolium*, and correlation coefficients of 0.172, 0.132, and 0.208 were obtained for the years 1957, 1958, and 1959 respectively.

DISCUSSION

A precise assessment of the importance that honeybees can assume in the pollination of lowbush blueberry is complicated by several factors. Blueberry is a native fruit and is produced on a commercial basis with a minimum of cultural care. Consequently a typical blueberry field contains a wide range of clonal types with variability in such qualities as age, time of bloom, colour and size of blossoms, and need for cross-pollination. There is wide variation between fields in density of stand and relative coverage by diploid or tetraploid species. Competing bloom is very common within and surrounding the fields, particularly in New Brunswick. Native bee densities vary between fields and between years. A solution to the problems of blueberry pollination, therefore, will in all probability await a detailed study of the influence of these factors. This paper reports on a rather general approach to the problem and the results obtained show the need for a more intensive study.

The data on fruit set in fields with and without the service of honeybees showed that, at least in some years, the set of fruit can be increased by the use of honeybees. The lack of a significant increase in set in 2 years out of 3, however, shows that an increased set cannot be guaranteed by adding honeybees to the pollinating force. It must also be remembered that these results are based on conditions in New Brunswick only, and more favourable results would be possible in other areas.

No counts of native bees were taken in this study because of limitation of time and personnel. It was assumed that, although variations in native bees would occur between fields, these variations would be compensated by the number of fields sampled.

The influence of weather on pollination cannot be overlooked in this study. In 1957 conditions were favourable for pollination. Clear, warm days were experienced during the major part of the blooming period. Rainfall was light and confined to the later hours of the day. Fruit set was considered average.

In 1958 the days were cloudy and cool, and rain was common during the period of bloom. This weather was adverse to bee activity and the set was well below average.

In 1959 the weather was again favourable. However, there was extreme variation in fruit set among fields in the Tower Hill area. This was due to the combined influences of weather and pollinator density. The days during bloom were unusually warm and plant development was rapid. Most of the blossoms opened within a 9-day period as contrasted with 19 and 16 days in 1957 and 1958. With such a short period of bloom a given density of native pollinators could not accomplish as much pollination as when the bloom period lasted twice as long. On the other hand the effect of adding a supply of honeybees would be most apparent in a year with a short bloom period. This is supported by the low set obtained in fields with native bees only, and by the greatly increased set which followed the addition of honeybees. Honeybees tend to expand their foraging range to competing bloom in adjacent fields. This habit takes on increased significance when there is a long period of bloom.

No significant increase in set could be obtained by increasing the number of honeybee colonies per acre. These results add support to the conclusion that increased set cannot be guaranteed by adding honeybees to supplement the native bee population.

An examination of the set obtained in fields with varying types of stand (with respect to coverage by tetraploid or diploid species of blueberry) showed no relationship between composition of stand and percentage fruit set. This lack of correlation rules out the theory that the higher set reported in Nova Scotia might be due to the very high percentage of the tetraploid *V. angustifolium*. New Brunswick fields show a more mixed type of stand.

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MONILINIA TWIG AND BLOSSOM BLIGHT OF LOWBUSH BLUEBERRY AND ITS CONTROL[1]

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ABSTRACT

Surveys showed twig and blossom blight of lowbush blueberries, caused by *Monilinia vaccinii-corymbosi*, to be prevalent in Nova Scotia and New Brunswick. The severity of the disease increased each successive year after burning.

Sclerotia remained viable for several years and gave rise to apothecia from late April till early June. Apothecia from sclerotia from lowbush blueberries were smaller than those reported from the highbush blueberry. When first isolated in culture the fungus produced micro- and macroconidia, but on subsequent transfer only microconidia were produced. The fungus could not be isolated from overwintered diseased leaves or twigs. Field inoculations readily reproduced the disease but inoculations in the greenhouse were unsuccessful.

Three applications of ferbam, zineb or thioneb dust gave good control of twig and blossom-blight. In practice, the disease is largely controlled by burning which destroys the overwintering mummy berries without killing the underground parts of the plant.

INTRODUCTION

A *Sclerotinia* twig blight of blueberries has long been known. Markin (3) in Maine reported it to be severe on both lowbush and highbush types in 1929. Although it was referred to simply as "*Sclerotinia* blight", the fungal species involved was presumably *Monilinia vaccinii-corymbosi* (Reade) Honey, described by Honey (2) as affecting highbush blueberry, and overwintering in the form of sclerotia or mummy berries. The fungus has also been found in the rabbiteye blueberry in Missouri (1).

Twig and blossom blight, also called mummy berry, as it occurs in the highbush blueberry, has been adequately described (2, 5). The present work, carried out in Nova Scotia and New Brunswick, was undertaken to study the disease on lowbush blueberry.

PREVALENCE OF THE DISEASE

Trace amounts of twig and blossom blight of lowbush blueberries (*Vaccinium myrtilloides* Michx. and *V. angustifolium* var. *laevifolium* House and var. *nigrum* (Wood) Dole), caused by *M. vaccinii-corymbosi*, were first observed in May, 1952, in 3 fields located in Kings County, Nova Scotia. Subsequently a survey of 24 fields in Charlotte County, New Brunswick, showed 17 of the fields to be infected. Thirteen contained only a trace of the disease, but in four fields over 50 per cent of the blossoms and twigs were affected.

Further surveys were made in 1956. Out of 39 fields in the New Brunswick area, 4 were free from the disease, 22 had trace infections, and 13 fields were severely infected. In Cumberland County, Nova Scotia, 9 fields were free, 12 had a trace and 2 were severely infected. The disease was generally more severe in second-crop fields that had been burned 3 years before.

[1]Contribution No. 1051 from Research Station, Canada Department of Agriculture, Kentville, N.S.

SYMPTOMATOLOGY

The disease first appears on the foliage about 2 to 3 weeks before full-bloom as dark brown areas frequently with water-soaked margins along the mid-rib towards the base of the leaf. The infection rapidly spreads to the twigs where similar symptoms develop (Figure 1), giving the affected twigs a drooping, withered appearance. Affected blossoms (Figure 2) turn brown and cling to the twigs. A few days after the first symptoms, an olive greyish-green mould appears at the base of affected leaves and often spreads down the petiole to the twig. The fungus frequently attacks the young fruit and replaces the host tissue with hyphae to form what is termed a mummy berry. The mummy berries are at first creamy-tan but as they develop, the skin of the berry falls off leaving a hard black sclerotium (Figure 3). About harvest time these mummified fruits usually fall to the ground but some remain attached to the plants till late in the fall.

ISOLATION OF ORGANISM AND ITS GROWTH IN CULTURE

The fungus could be readily isolated from newly infected twigs or blossoms and produced both macro- and microconidia in culture. However, when transfers were made, either by mycelial plug or spore suspension, to fresh potato dextrose or V-8 juice agar (4), only microconidia were produced. Cultures derived from single ascospores also produced only microconidia. Cultures held on potato dextrose agar at 46°F. for 5 to 6 months often produced a few scattered black sclerotia but apothecia were not observed in culture. Mummy berries, surface sterilized in 2 per cent chlorine solution and planted in agar, produced mycelia and microconidia.

MORPHOLOGY

The ascocarps of *M. vaccinii-corymbosi* developing from mummy berries produced in highbush and lowbush blueberries were compared for size of apothecia, asci, ascospores and paraphyses. The results presented in Table 1 are the average of 100 measurements of each structure with Honey's (2) dimensions from highbush blueberry given for comparative purposes. The data show that the apothecia from highbush blueberry are similar to those described by Honey (2), whereas those from the lowbush blueberry are somewhat smaller. The asci, ascospores and paraphyses from both lowbush

TABLE 1.—MEASUREMENTS OF APOTHECIA, ASCI, ASCOSPORES AND PARAPHYSES OF *M. VACCINII-CORYMBOSI*

Material	Source of apothecia		
	Lowbush	Highbush	Highbush [Honey (2)]
Width of apothecia	3-7 mm.	6-13 mm.	5-10 mm.
Height of apothecia	6-22 mm.	10-34 mm.	10-35 mm.
Asci	178-242 x 12-17μ	171-264 x 12-17μ	200-260 x 10-12μ
Ascospores	16-23 x 8-12μ	16-22 x 8-12μ	14-18 x 9-10μ
Paraphyses	1.6-4.2μ	1.2-4.3μ	2-3μ

and highbush blueberries appear to be somewhat more variable in size than Honey's (2) and, except for the length of the asci, tend to be larger. Apart from these variations in dimensions the apothecia from lowbush blueberries fit Honey's (2) description. It was also observed that each sclerotium from the lowbush blueberry produced only one or two apothecia while the ones from highbush usually produced three to five.

DEVELOPMENT OF APOTHECIA

Apothecia, arising from overwintering mummy berries, were first found in the spring of 1957 in a lowbush blueberry field near Kentville, Nova Scotia. Apothecial initials (Figure 4) were observed on April 18 and mature apothecia (Figure 5) were found on May 2. Field observations at 4- to 7-day intervals showed that production of apothecia reached a maximum from May 10 to 17 and ceased after June 5. Only a small percentage of the mummy berries or sclerotia produced apothecia. Apothecia were more prevalent on mummy berries in contact with the soil or buried in the duff than in those lying on the surface of the ground.

During June, 1957, mummy berries which had not developed apothecia were collected and stored in the laboratory at room temperature. In September, further collections were made of freshly developed mummy berries. These mummy berries and those collected in June were overwintered in an outdoor sclerotia-bed prepared by removing the grass and weeds from a plot of clay-loam soil. Half of the mummy berries were buried to a depth of a quarter-inch and the other half were partially pressed into the surface of the soil.

Observations on the development of apothecia in the sclerotia-bed were made at frequent intervals during the spring of 1958, 1959 and 1960. The results for 1958 and 1959 are presented in Table 2. The data recorded in this table show the number of apothecia present on a given day but do not give the total percentage germination of sclerotia. However, 18 of the 27 buried produced apothecia (14 in 1958 and 4 in 1959) but only 6 out of 27

TABLE 2.—NUMBERS OF APOTHECIA OBSERVED ON OLD AND NEW SCLEROTIA AT DIFFERENT DATES IN 1958 AND 1959

Observation dates	Buried in soil				On soil surface			
	Old sclerotia (27 planted)		New sclerotia (45 planted)		Old sclerotia (27 planted)		New sclerotia (45 planted)	
	1958	1959	1958	1959	1958	1959	1958	1959
April 21	2	0	0	0	0	0	0	0
28	6	—	2	—	0	—	0	—
May 4	14	3	9	1	0	1	0	1
11	13	1	21	2	0	4	1	1
16	13	1	22	5	0	6	2	6
20	12	4	22	6	0	5	2	6
26	1	2	8	6	0	2	2	6
June 1	—	0	4	1	0	0	4	1
9	0	—	0	—	0	—	2	—
15	—	0	—	0	—	0	—	0

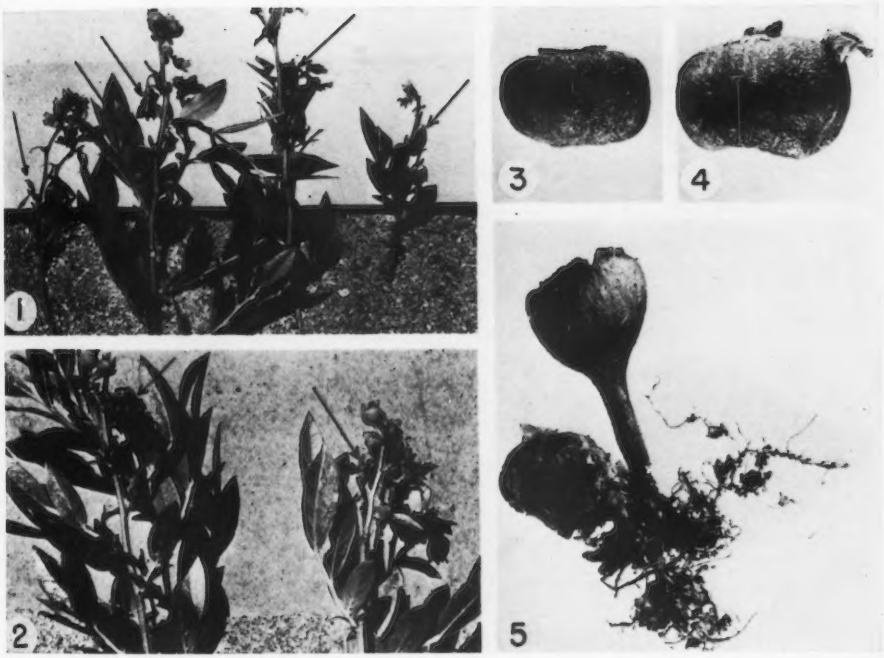

FIGURE 1. Blueberry twigs infected with *M. vaccinii-corymbosi*. ½X.
FIGURE 2. Blueberry blossoms infected with *M. vaccinii-corymbosi*. ½X.
FIGURE 3. Mummy berry. 6X.
FIGURE 4. Mummy berry showing apothecial initial. 5X.
FIGURE 5. Mummy berry with mature apothecium. 5X.

(none in 1958 and 6 in 1959) developed when they were placed on the surface of the soil. In the latter case, the development occurred probably as a result of natural burial. Similar results were obtained with new sclerotia. It can be considered that sclerotia may be dormant in the soil for a year or more and germinate when conditions become suitable. In both years apothecial initials were first observed on April 9. Only two apothecia were found in 1960, both of which were from buried sclerotia. One was from sclerotia collected in June, 1957, and the other from the 1957 fall collection.

Apothecia were first found on April 21 and April 30 in 1958 and 1959, respectively. During 1958, maximum apothecial development occurred between April 28 and May 20, whereas in 1959 it was from May 4 to 26. Rains were more frequent and the mean temperature was higher by 3°F. in April, 1958, than in April, 1959. These factors might account for the earlier appearance and development of apothecia in 1958. Dates recorded for apothecial development in the artificial bed agree with those taken under natural field conditions.

OVERWINTERING OF ORGANISM IN INFECTED PLANT PARTS

Blueberry plants infected with *M. vaccinii-corymbosi* were treated as follows:

1. Blighted leaves were collected and put in cheesecloth bags and placed out of doors on the ground in a partially shaded location.
2. Blighted twigs and shoots were stored in an unheated shed.
3. Blighted blueberry shoots on infected plants were tagged in the field.

In the spring of 1957, material from treatments 1 and 2 were placed in moist chambers and left at room temperatures. No evidence of *Monilinia* was observed. Eight out of twenty-six shoots tagged in the field appeared healthy. In the remaining 18 cases, the fungus had extended into the shoot and caused a twig dieback. Repeated attempts to isolate *Monilinia* from these diseased twigs yielded negative results. This evidence suggests that *M. vaccinii-corymbosi* does not overwinter in the infected twigs or leaves.

PLANT INOCULATIONS

During the bloom period in 1956 healthy blueberry shoots, in a first-crop field, were inoculated by atomizing the plants with a conidial suspension of *M. vaccinii-corymbosi*. This suspension was obtained by scraping and washing the conidia from field-infected leaves. Immediately following inoculation, the shoots were covered with polyethylene bags. In 4 to 6 days, during which the temperature ranged from 43 to 54°F., and the weather was overcast and wet, the shoots became severely blighted and the infected areas became covered with mycelium and spores of *M. vaccinii-corymbosi*. No infection could be found in adjacent blueberry plants.

During these studies many attempts were made in the greenhouse to infect blueberry plants by inoculating them at various stages of development with conidia and ascospore suspensions of the fungus, but all yielded negative results. Negative results were obtained also with wound inoculations on blueberry shoots using mycelial and conidial inoculum.

CONTROL

General observations on the incidence of twig and blossom blight of lowbush blueberry indicate that this disease is largely controlled by burning, which, in the normal culture of lowbush blueberries, is carried out every 2 or 3 years. No blossoms are produced in the year of burning or year of sprout-growth. The incidence of disease usually builds up gradually in the fields after the burning, blight being observed rarely in the sprout year, commonly in fields bearing their first crop, and most severely in second-crop fields. In fields where the disease has been prevalent and burning incomplete, the incidence of disease in the unburned areas is usually very high.

Field observations show that burning destroys many of the mummy berries and, since it has been shown that the fungus does not overwinter as leaf and twig infections, the control obtained is probably proportional to the destruction of the mummy berries or sclerotia.

The results of an experiment in which various chemical dusts were tested for their effectiveness in the control of twig and blossom blight of lowbush blueberry are given in Table 3. This experiment was carried out in a first-crop field at Tower Hill, New Brunswick, which had a known history of infection. The dusts indicated in the table were applied to randomized and replicated plots on May 31, June 12 and 19, with a Niagara Cyclone-Junior hand duster at the rate of 15 pounds per acre per application. Disease incidence was evaluated on July 11 by throwing a 0.5 square foot quadrate frame 20 times in each plot and recording the number of infected and non-infected shoots within the frame. The number of shoots enclosed by the frame varied from about 12 to 30. Analysis of the data showed that the dusts were equally effective and all gave a statistically significant reduction in disease incidence. The measure of control was actually greater than that indicated in the table since the reduction in number of diseased plants was accompanied by a comparable reduction in disease severity on individual plants. Equivalent control has been obtained both in demonstration plots and under commercial conditions. Standard recommendations for ferbam or zineb dust treatments have been made on the basis of these results. These treatments are very effective when used in conjunction with systematic burning.

TABLE 3. — INFLUENCE OF FUNGICIDE DUSTS ON THE INCIDENCE OF *M. VACCINII-CORYMBOSI* TWIG AND BLOSSOM BLIGHT OF BLUEBERRY

Treatment[1]	Per cent infected plants
Ferbam, 7.6%	2.5
Zineb, 3.9%	2.9
Thioneb, 5.0%	1.9
Check	5.1
Necessary difference, 5% level	2.07

[1] Ferbam (Ferbam 7 dust) ferric dimethyldithiocarbamate (Niagara Brand Spray Co. Ltd., Burlington, Ont.); Zineb (Thiogreen Dust Fungicide), zinc ethylenebisdithiocarbamate, 3.9% (Green Cross Products, Woodstock, N.B.); Thioneb, polyethylene thiuram sulphide, 5%, (Naugatuck Chemicals, Division of Dominion Rubber Co. Ltd., Elmira, Ont.)

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THE INHERITANCE OF LEAF RUST RESISTANCE IN SEVEN VARIETIES OF COMMON WHEAT[1]

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ABSTRACT

The inheritance of seedling resistance to races 1a, 5a, 11, 15a and 126a of leaf rust was studied in the varieties Exchange and Selkirk and to races 1a and 15a in the varieties Lee, Gabo, Timstein, Mayo 52 and Mayo 54. Thatcher was used as the susceptible variety. Rust tests were carried out on F_1 and F_2 populations of diallel crosses among these varieties and on F_3 families from the backcrosses to Thatcher. Two genes were found. One gene Lr_E conditions a (2) type reaction to all five races in Exchange and Selkirk. The other gene Lr_L conditions a (;1=) type reaction to races 1a and 15a in all seven varieties. Isogenic lines possessing these genes are being developed in the varieties Prelude and Thatcher. The importance of such lines in future genetic studies and their application in other biological studies are discussed.

The increase in amount of leaf rust found on Lee and Selkirk in Canada during the period 1951-1958 is accounted for by the increase of races which render the gene Lr_L ineffective in these two varieties.

INTRODUCTION

The reduction in wheat yields caused by attacks of *Puccinia recondita* Rob. ex Desm. (*P. triticina* Eriks.) has not been fully appreciated probably because of the comparison with the more spectacular destruction caused by stem rust. However, Chester (3) has pointed out that, even though epidemics caused by leaf rust are usually milder in form, the yearly "erosion" of yield, together with such disastrous epiphytotics as occurred in 1938, may make the losses to leaf rust equal to those from stem rust in a similar period. Leaf rust must, therefore, be considered a major disease of wheat.

The life-history and epidemiology of the leaf rust organism have been studied in some detail. Although the organism has been shown to be independent of its alternate host in the North American pandemic region, it has been shown to exist in many physiologically specialized forms which may be differentiated on the basis of their ability to attack certain varieties. In addition, a number of studies have been conducted to demonstrate the mode of inheritance of resistance genes in a few varieties. Such studies as the foregoing form the basis for breeding resistant varieties.

When a resistant variety is introduced it spreads rapidly over a wide area and, since it has been bred for resistance to the races prevalent at that time, it immediately suppresses them. However, races which are able to attack it increase in the rust population and after a few years the variety can no longer be considered fully resistant. An example of this loss of resistance is shown by the Canadian-grown varieties Lee and Selkirk. At the time of their release both varieties possessed a high degree of resistance but Lee is now susceptible and Selkirk only moderately resistant to the present races. Because of this physiologic variation in the organism the plant breeder must continually breed for the changing race pattern and the geneticist must find new genes for resistance.

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The investigations reported herein form part of a larger program designed to establish the mode of inheritance of new resistance genes and to isolate them in a common genetic background where their mode of action may be more closely studied. In this paper, seven varieties of common wheat have been genetically analysed for their resistance to a number of leaf rust races. Five races were used to test for the inheritance and interrelationships of resistance genes in the varieties, Selkirk, Exchange, Lee, Gabo, Timstein, Mayo 52 and Mayo 54.

REVIEW OF LITERATURE

The early work on resistance to leaf rust was reviewed by Ausemus (1) in 1943, and later by Ausemus *et al.* (2) in 1946. The first paper dealt primarily with the subject of breeding resistant varieties, while in the latter the authors summarized the genetic information published to that time.

The existence of physiological specialization in leaf rust of wheat was first demonstrated by Mains and Jackson (13) in 1921, when they showed that differences existed among a number of collections of leaf rust in their ability to attack Malakof and four numbered selections of wheat. By 1923 they had succeeded in differentiating 12 strains on 7 varieties (14), and by 1926 had established a set of 11 differential hosts (15). By 1932, Johnston and Mains (9) had identified 53 races, 39 of which had been collected in North America. In 1929, Waterhouse (18) found 2 strains in Australia. In the same year Johnston and Melchers (10) established the existence of two distinct types of resistance to leaf rust — adult plant resistance effective only during the adult stage of the plant, and seedling resistance effective throughout the life of the plant.

Genes Lr_1, Lr_2 and Lr_3, named by Ausemus *et al.* (2), are found in the varieties Malakof, Webster and Fulcaster, respectively. These genes were located by Mains, Leighty and Johnston (16) in 1926 and this study is the first recorded work on the inheritance of resistance to leaf rust carried out in North America. Genes Lr_4, Lr_5, Lr_6, Lr_7 and Lr_8 were found in a Purdue University hybrid, 3369-61-1-1-10-8, by Fitzgerald, Caldwell and Nelson (5), 1957.

Since the publication of the review by Ausemus *et al.* (2), a number of excellent reports have been published dealing with different aspects of resistance to this disease. Only those papers which are concerned with the varieties used in this investigation will be reviewed here.

Levine, Ausemus and Stakman (12) in 1951 summarized the reactions of a number of varieties of wheat to many races of leaf rust. Among the varieties mentioned, Exchange was considered resistant to all races including races 1, 5, 11, 15 and 126; Gabo was susceptible to race 11 but resistant to the other four; Lee and Timstein were considered resistant to all five; and Thatcher, used herein as the susceptible parent, was susceptible to all five.

Wu and Ausemus (20) in 1953 reported Lee to be moderately resistant to leaf rust. In the seedling stage it was resistant to all races to which it was tested except race 12 and a Canadian race 11. In tests to race 126,

resistance was found to be governed by a single recessive gene while for resistant to race 5 a single dominant gene appeared responsible. The two genes were considered to be linked with a recombination value of 21 ± 2.7 per cent. Adult plant resistance, which was also found in Lee, was believed to be conditioned by two independent, partially recessive genes which are additive in effect.

Heyne and Johnston (8), in 1954, showed that Timstein carries both seedling and adult forms of resistance. In the seedling stage reaction types were (0;) for race 15, (1 to 1+) for races 9, 5 and 126 and (1+ to 2) for race 44. Seedling resistance to races 5, 9, 15, 44 and 126 was thought to be controlled by one major recessive gene with one or more modifying genes. It was postulated that adult plant resistance is controlled by a single major recessive factor whose expression is dependent on several modifying factors.

Choudhuri (4) in 1959, working on F_2 lines of a cross between Selkirk with Mentana-Rhodesian, found that resistance to both 5a and 15a was controlled by two genes. One of these genes which he has named Lr_{10} conditions a (0;1-) reaction to these two races and is epistatic to one in Mentana-Rhodesian which also gives resistance to the same races. The second gene Choudhuri considers to be Lr_2.

MATERIALS AND METHODS

Seed of the varieties Exchange (C.I. 12635), Mayo 52 (Entry No. 257, 1953 International Wheat Rust Nursery) and Mayo 54 (Entry No. 176, 1954 I.W.R.N.) was obtained from the World Wheat Collection, courtesy of D. Ward; seed of Selkirk (R.L. 2769) from the Cereal Breeding Laboratory, Winnipeg; seed of Lee (C.I. 12488), Gabo (C.I. 12795) and Timstein (C.I. 12347) from the University of Minnesota; and seed of Thatcher (C.I. 10003) from the University of Saskatchewan.

Exchange has good leaf rust resistance, as it combines adult plant resistance which is operative during the period from the appearance of the flag leaf to maturity with seedling resistance which is very marked toward some races and moderately so toward others. The variety was selected from among the progeny of the cross Warden x Hybrid English at Purdue University. Warden, according to Pugsley*, is an old Australian variety, but the origin of Hybrid English is unknown. On the basis of greenhouse tests, Warden appears to have the full seedling resistance of Exchange, but has none of its adult plant resistance. The latter must be presumed to have been derived from the Hybrid English parent.

Mayo 52 and Mayo 54 are resistant to many of the races to which Lee is resistant. Both of these varieteis were derived from the cross, Mayo 48 x (Egypt Na 101 x Timstein).

The seedling resistance of Selkirk is similar to that of Exchange, but it has none of the adult plant resistance of the latter. Selkirk was selected from among the progeny of the cross (McMurachy x Exchange) x Redman*.

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*Personal communication

Lee, which was widely grown as a commercial variety, showed high resistance to all of the prevalent races at the time of its release. In recent years it has become susceptible to the changing pattern of races. It was selected from the cross Hope x Timstein at the University of Minnesota. Gabo has leaf rust resistance similar to Lee and was derived from the cross Gaza x Bobin[2] in Australia. Its resistance, therefore, is probably of durum origin. Timstein, which was originally considered to have been derived from the cross *Triticum timopheevi* x Steinwedel, has been found by Watson and Stewart (19) and Knott and Anderson (11) to be a sister selection of Gabo.

Thatcher, which was used as the susceptible variety, is susceptible to a large number of leaf rust races.

The races used in the present study and their cultures (shown in parentheses) were as follows: 1a (177-54), 5a (60-56), 11 (3-56), 15a (4-56) and 126a (1-56). The postscript "a" simply denotes the fact that this race, while conforming to the pattern for the race on the standard differentials, is capable of attacking Renown. Initial inoculum was purified by D. J. Samborski of the Winnipeg Research Station and increased on the susceptible variety, Little Club.

Diallel crosses were made between all varieties. F_1 plants of the crosses between the seven resistant varieties and Thatcher were backcrossed to the latter parent.

Exchange and Selkirk crosses and backcrosses were tested to all five races, whereas when Gabo, Lee, Timstein, Mayo 52 or Mayo 54 was the resistant parent, they were tested only to races 1a and 15a. The major tests were with F_2 backcross families and were conducted in growth cabinets at about 70°F. The F_1 and F_2 of single crosses, as well as small populations of representative segregating families of the F_2 backcross, were tested under greenhouse conditions. Growth cabinet populations were grown in pots while those grown in the greenhouse were grown in 4-foot rows spaced 3 inches apart with about 50-60 plants per row.

Seedling inoculations were effected in the following manner:

1. *In the growth cabinet.* Leaves were wetted thoroughly with a fine spray nozzle connected to the water hose. Spores were mixed with talc in an approximate ratio of 1 part spores to 50 parts talc and dusted on the leaves using a small "puffer" bottle. Lights, fan and compressor were then shut off for a period of approximately 18 hours with occasional spraying to maintain the water film on the leaves.

2. *In the greenhouse.* Plants grown in beds were inoculated in the manner described above, and the bed covered with a heavy canvas which was placed over the plant supports on the side of the beds with the canvas hanging down the side to enclose the bed completely.

Rusted seedlings were read according to the system described by Stakman *et al.* (17).

The Chi-Square test for goodness of fit described by Goulden (7) was used in the analysis of results.

TABLE 1.—REACTION OF PARENTAL VARIETIES TO LEAF RUST RACES IN THE SEEDLING STAGE

Varieties	Races				
	1a	5a	11	15a	126a
Exchange, Selkirk	VR	MR	MR	VR	MR
Lee, Gabo, Timstein Mayo 54, Mayo 52	VR	S	S	VR	S
Thatcher	S	S	S	S	S

VR very resistant (;1 =)
MR moderately resistant (2)
S susceptible (4)

TABLE 2.—REACTION OF F_1 PLANTS OF THE DIALLEL CROSSES IN THE SEEDLING STAGE TO FIVE LEAF RUST RACES

Varieties	Selkirk		Lee, Gabo Timstein Mayo 52, Mayo 54		Thatcher	
Races	1a, 15a	5a, 11, 126a	1a, 15a	5a, 11, 126a	1a, 15a	5a, 11, 126a
Exchange, Selkirk	VR	MR	VR	MS-S	MR	MS-S
Lee, Gabo, Timstein Mayo 52, Mayo 54			VR	S	MR	S

TABLE 3.—REACTION OF F_2 POPULATIONS OF THE DIALLEL CROSSES IN THE SEEDLING STAGE TO FIVE LEAF RUST RACES

Varieties	Selkirk		Lee		Gabo		Timstein		Mayo 52		Mayo 54		Thatcher	
Races	1a, 15a	5a, 11 126a	1a, 15a	5a, 11 126a	1a, 15a	5a, 11 126a	1a, 15a	5a, 11 126a	1a, 15a	5a, 11 126a	1a, 15a	5a, 11 126a	1a, 15a	5a, 11 126a
Exchange	VR	MR	VR	Seg	VR	Seg	VR	Seg	VR	Seg	VR	Seg	Seg	Seg
Selkirk			VR	Seg	VR	Seg	__*	__*	VR	Seg	VR	Seg	Seg	Seg
Lee					VR	S	VR	S	VR	S	VR	S	Seg	S
Gabo							VR	S	VR	S	VR	S	Seg	S
Timstein									VR	S	VR	S	Seg	S
Mayo 52											VR	S	Seg	S
Mayo 54													Seg	S

*The F_1 was dwarfed and produced no seed

RESULTS

In this paper, F_2 backcross families were used to determine the number of genes possessed by each of the resistant varieties, the number of families being sufficiently large to ensure the accuracy of the conclusions. Where possible, the segregations observed within the segregating families were used to test further the hypotheses suggested by the ratio of segregating to susceptible families. F_1 data were used to establish the dominance relationships and F_2 data to establish whether the varieties have genes or alleles in common.

The reaction of parental varieties to the races used are shown in Table 1.

Selkirk and Exchange conform to the same pattern of reaction as might be expected when it is considered that the Selkirk leaf rust resistance was derived from Exchange. The remaining five varieties, Lee, Gabo, Timstein, Mayo 54 and Mayo 52, are grouped together since each of them gives the same pattern of reaction. Again this pattern is not surprising, as Gabo and Timstein are considered sister selections from the same cross and the remaining three varieties have Timstein in their parentage. Thatcher, as previously mentioned, is susceptible to all five races.

In Table 2, the reactions of F_1 plants to the various races are summarized. Each cell in this table represents an F_1 from the parents shown in the row and column in which the cell occurs. The reactions to races 1a and 15a and to races 5a, 11 and 126a are grouped together since the reaction was identical in any cross within these groupings. Further, the varieties Exchange and Selkirk on the one hand, and the varieties Lee, Gabo, Timstein, Mayo 52 and Mayo 54 on the other, were also placed in two groups, since reactions to either of the groups of races was similar for varieties within these groups.

The reactions for F_2 populations of the diallel crosses are shown in Table 3. Here the races are grouped in the same manner as in Table 2. It is apparent that Selkirk and Exchange have one or more genes in common for resistance to races 5a, 11 and 126a as was expected. It also appears that all seven resistant varieties carry one or more allelic genes for resistance to races 1a and 15a.

In order to demonstrate the relationships and number of genes present in each variety the backcross data are presented for each of the two groups of varieties mentioned above.

Exchange and Selkirk

Table 4 shows the results obtained when backcross families of Exchange x Thatcher^2 and Selkirk x Thatcher^2 were inoculated to race 1a.

It is clear from the data that two genes for resistance to race 1a are carried by both Exchange and Selkirk. In each case a satisfactory fit was obtained for a 2-gene backcross ratio in the proportion of 3 segregating to 1 susceptible family. Of the 50 backcross families of Exchange x Thatcher^2, 11 gave a segregation of 3 resistant (;1=) to 1 susceptible; 14 gave a segregation of 3 moderately resistant (2,3-) to 1 susceptible; 10 gave a 12 re-

sistant to 3 moderately resistant to 1 susceptible; and 15 families were susceptible. This is a good fit to the expected 1:1:1:1 ratio with a P value of .70-.80. Similarly, of 84 Selkirk x Thatcher^2 backcross families, 24 gave a ratio of 3 resistant to 1 susceptible; 21 gave a ratio of 3 moderately resistant to 1 susceptible; 18 gave a ratio of 12 resistant to 3 moderately resistant to 1 susceptible; and 21 families were susceptible. This is again

TABLE 4.—RESULTS OF SEEDLING TESTS ON F_2 FAMILIES FROM THE BACKCROSSES EXCHANGE X THATCHER^2 AND SELKIRK X THATCHER^2 TESTED TO RACE 1A

	Number of families				Total
	Seg 3R:1S	Seg 3MR:1S	Seg 12R:3MR:1S	S	
Exchange x Thatcher^2	11[1]	14[2]	10[3]	15	50
Expected (1:1:1:1)	12.5	12.5	12.5	12.5	50
P			.70 – .80		
Selkirk x Thatcher^2	24[4]	21[5]	18[6]	21	84
Expected (1:1:1:1)	21	21	21	21	84
P			.80 – .90		

The ratios within segregating families were as follows:

[1]193R:77S plants — P for a 3:1 ratio = .20 – .30
[2]226MR:84S plants — P for a 3:1 ratio = .30 – .50
[3]164R:38MR:15S plants — P for a 12:3:1 ratio = .80 – .90
[4]514R:195S plants — P for a 3:1 ratio = .30 – .50
[5]445MR:166S plants — P for a 3:1 ratio = .20 – .30
[6]259R:75MR:27S plants — P for a 12:3:1 ratio = .30 – .50

TABLE 5.—RESULTS OF SEEDLING TESTS ON F_2 FAMILIES FROM THE BACKCROSSES EXCHANGE X THATCHER^2 AND SELKIRK X THATCHER^2 TESTED TO RACE 15A

	Number of families				Total
	Seg for R	Seg for MR	Seg for R and MR	S	
Exchange x Thatcher^2	13	13	11	15	52
Expected (1:1:1:1)	13	13	13	13	52
P			.80 – .90		
Selkirk x Thatcher^2	19	21	15	18	73
Expected (1:1:1:1)	18.25	18.25	18.25	18.25	73
P			.80		

TABLE 6.—RESULTS OF SEEDLING TESTS ON F_2 FAMILIES FROM THE BACKCROSSES EXCHANGE X THATCHER[2] AND SELKIRK X THATCHER[2] TESTED TO RACE 5a

	Number of families		Total
	Seg 1MR:3S	S	
Exchange x Thatcher[2]	24[1]	26	50
Expected (1:1)	25	25	50
P	.70 – .80		
Selkirk x Thatcher[2]	37[2]	42	79
Expected (1:1)	39.5	39.5	79
P	.50 – .70		

The ratios within segregating families were as follows:
[1]271MR:905S plants P for a 1:3 ratio = .10 – .20
[2]394MR:1139S plants P for a 1:3 ratio = .50 – .70

a good fit to the expected 1:1:1:1 ratio with a P value of .70-.80. Segregations within the segregating families gave satisfactory fits to the expected ratios. Each of the two genes appears to behave in a dominant manner with the gene responsible for the (;1=) type reaction being epistatic to that giving the (2) type reaction.

When tested to race 15a the backcross families showed a similar segregation to that shown for race 1a, but here the segregation within segregating families was quite erratic probably because of environmental conditions. However, it was not difficult to differentiate between families segregating for the (;1=) type, the (2) type and for both. Results of tests to this race are presented in Table 5.

Of the 52 backcross families of Exchange x Thatcher[2], 13 segregated for the (;1=) reaction; 13 for the (2,3-) reaction; 11 for both types; and 15 were susceptible. Of 73 families of Selkirk x Thatcher[2], 19 segregated for (;1=); 21 for (2) type; 15 for both types; and 18 were susceptible. Both ratios are good fits to the expected 1:1:1:1 ratio with P values of .80-.90 and .80, respectively. Again, two genes appear to be present, one conditioning high resistance and the second a moderate type of resistance. In each case where the family was tested to both races, the reaction was the same. It appears, therefore, that these two genes condition resistance to both races 1a and 15a.

Results of tests of the backcross families to race 5a are given in Table 6. Of the 50 families of Exchange x Thatcher[2], tested to this race, 24 segregated 1 resistant (2 type) to 3 susceptible and 26 were susceptible which fits a 1:1 or a 1-gene backcross ratio with a P value of .70-.80. Similarly,

TABLE 7.—RESULTS OF SEEDLING TESTS ON F_2 FAMILIES FROM THE BACKCROSSES EXCHANGE X THATCHER[2] AND SELKIRK X THATCHER[2] TESTED TO RACE 11

	Number of families		Total
	Seg 1MR:3S	S	
Exchange x Thatcher[2]	26[1]	27	53
Expected (1:1)	26.5	26.5	53
P	.80 – .90		
Selkirk x Thatcher[2]	36[2]	39	75
Expected (1:1)	37.5	37.5	75
P	.70 – .80		

The ratios within segregating families were as follows:
[1]173MR:469S plants — P for a 1:3 ratio = .20 – .30
[2]204MR:703S plants — P for a 1:3 ratio = .05 – .10

TABLE 8.—RESULTS OF SEEDLING TESTS ON F_2 FAMILIES FROM THE BACKCROSSES EXCHANGE X THATCHER[2] AND SELKIRK X THATCHER[2] TESTED TO RACE 126a

	Number of families		Total
	Seg 1MR:3S	S	
Exchange x Thatcher[2]	26[1]	27	53
Expected (1:1)	26.5	26.5	53
P	.80 – .90		
Selkirk x Thatcher[2]	40[2]	38	78
Expected (1:1)	39	39	78
P	.80		

The ratios within segregating families were as follows:
[1]145MR:435S plants — P for 1:3 ratio = .80 – .90
[2]224MR:675S plants — P for 1:3 ratio = .95 – .98

among the 79 families of Selkirk x Thatcher[2], 37 segregated 1 resistant to 3 susceptible, and 42 were susceptible, also a good fit to the 1:1 ratio (P value .50-.70). Ratios within the segregating families from both crosses gave satisfactory fits to a 1:3 ratio. Both Exchange and Selkirk, therefore, have a single recessive gene which conditions moderate resistance to race 5a.

Table 7 shows the results of tests to race 11. Fifty-three backcross families of Exchange x Thatcher^2 were tested. Of these, 26 were found to be segregating 1 resistant to 3 susceptible, and 27 were susceptible. Among the 75 families of Selkirk x Thatcher^2, 36 segregated 1 resistant to 3 susceptible and 39 were susceptible. Both ratios fit a 1:1 ratio, with P values of .80-.90 and .70-.80, respectively. Ratios within segregating families support the hypothesis that Selkirk and Exchange carry a single recessive gene for moderate resistance to race 11.

The data for seedling tests of Exchange and Selkirk backcross families to race 126a are presented in Table 8. Of the 53 families of Exchange x Thatcher^2 which were tested, 26 segregated 1 moderately resistant to 3 susceptible, and 27 were susceptible. In the 78 families of Selkirk x Thatcher^2, 40 segregated 1 moderately resistant to 3 susceptible, and 38 were susceptible. Both ratios fit the 1:1 ratio expected with probabilities of .80-.90 and .80, respectively. The segregations within segregating families support the hypothesis of a single recessive gene for moderate resistance carried by the two varieties for race 126a.

When the data for races 5a, 11 and 126a are considered collectively, each family which segregated for one of these races also segregated for the other two, and similarly those which were susceptible were susceptible to all three. It is, therefore, apparent that the same gene is responsible for resistance to all three races.

TABLE 9.—RESULTS OF SEEDLING TESTS ON F_2 FAMILIES FROM THE BACKCROSSES OF EXCHANGE AND SELKIRK TO THATCHER, FAMILIES ARRANGED IN A CONTINGENCY TABLE OF RACES 1a AND 15a WITH RACES 5a, 11 AND 126a

	Races 1a and 15a				Total	Expected (1:1)	P
	Number of families						
	Seg 3R:1S	Seg 3MR:1S	Seg 12R:3MR:1S	S			
Exchange x Thatcher^2 Races 5a, 11, 126a							
Seg 1MR:3S		13	10		23	24.5	.50—.70
S	11			15	26	24.5	
Expected (1:1:1:1)	12.25	12.25	12.25	12.25	49		
P	.70 — .80						
Selkirk x Thatcher^2 Races 5a, 11, 126a							
Seg 1MR:3S		21	18		39	42	.50—.70
S	24			21	45	42	
Expected (1:1:1:1)	21	21	21	21	84		
P	.80 — .90						

Table 9 is a summary of the data on Exchange and Selkirk backcross families arranged in a contingency table with races 1a and 15a grouped together against races 5a, 11 and 126a also grouped together. The number of families under each category represent those which were tested to all five races. The data clearly indicate that the gene giving moderate resistance to races 1a and 15a is the same gene which governs moderate resistance to races 5a, 11 and 126a. What appears strange, however, is that this gene appears to act as a dominant in the first instance to races 1a and 15a, but as a recessive to the latter three races. This could be a result of some difference in the environmental conditions under which the two sets of races were tested, or an actual difference. A few representative families were tested to the different races under the same environment and it appears that, although some difference does exist, it is less evident than was at first supposed. The heterozygotes, when tested with races 1a and 15a, appeared to be nearer the resistant than the susceptible class; those with races 5a and 11 appeared to be nearer the susceptible class; and those for race 126a were in the moderately susceptible class. For races 1a and 15a the heterozygotes were classed as resistant and for the remaining three races were classed as susceptible.

Lee, Gabo, Timstein, Mayo 52 and Mayo 54

These five varieties are considered together since it is considered from their reactions and parentage that all five have similar resistance. In Table 10 the data for Lee, Gabo and Timstein backcrosses are shown for reaction to race 1a. Of the 83 Lee x Thatcher^2 families, 38 segregated 1 resistant to 3 susceptible, and 45 were susceptible; of 40 Gabo x Thatcher^2 families, 19 segregated 1 resistant to 3 susceptible, and 21 were susceptible; and of 67 Timstein x Thatcher^2 families, 39 segregated 1 resistant to 3 susceptible, and 28 were susceptible. All three groups of families gave a satisfactory fit

TABLE 10.—RESULTS OF SEEDLING TESTS ON F_2 FAMILIES FROM THE BACKCROSSES OF LEE, GABO AND TIMSTEIN TO THATCHER FOR RACE 1a

	No. of families		Total
	Seg 1R:3S	S	
Lee x Thatcher^2	38[1]	45	83
Expected (1:1)	41.5	41.5	83
P	.30 — .50		
Timstein x Thatcher^2	39[3]	28	67
Expected (1:1)	33.5	33.5	67
P	.10 — .20		

	No. of families		Total
	Seg 1R:3S	S	
Gabo x Thatcher^2	19[2]	21	40
Expected (1:1)	20	20	40
P	.70 — .80		

[1]pop.1 228R:757S P for 1:3 ratio = .10 — .20
pop.2 74R: 24S P for 3:1 ratio = .70 — .80
[2]pop.1 128R:353S P for 1:3 ratio = .30 — .50
pop.2 129R: 33S P for 3:1 ratio = .20 — .30
[3]pop.1 204R:543S P for 1:3 ratio = .10 — .20
pop.2 109R: 40S P for 3:1 ratio = .50 — .70

to a 1:1 ratio (P values of .30-.50, .70-.80 and .10-.20) indicating that each variety carries a single gene for resistance which, on the basis of the original tests, acted in a recessive manner. A second smaller test was run using a few segregating families in the greenhouse and a reversal to a dominant mode of reaction was observed. The results from these are shown beneath the table as Population 2. The last-mentioned test was suggested by three observations: the lack of segregation in F_2 of crosses of Exchange and Selkirk with these varieties when tested to race 1a; the dominance of the high-resistance gene in Selkirk and Exchange for resistance to 1a, and its recessiveness in Lee, Gabo and Timstein; and the dominant reaction shown by the Mayo varieties, which according to the F_2 data appear to have a gene in common with Lee, Gabo and Timstein. The results obtained indicate that the reaction of the heterozygotes is influenced by environment and may appear more or less resistant depending upon the conditions under which the test is conducted. Under growth cabinet conditions, the heterozygotes appeared to be more susceptible than under the greenhouse conditions where the second population was grown. Since only one gene is present in each variety (and from the F_2 data it was shown that these three varieties have a gene or allele in common), resistance in all three varieties must be located at the same locus. Indeed, it must be the same gene, as each of the three varieties have the Timstein background, namely, Lee, from Hope x Timstein, Timstein itself, and Gabo, a sister selection of Timstein.

Results from the tests of backcross families of Mayo 52 and Mayo 54 x Thatcher[2] to race 1a are shown in Table 11. Of 52 families of Mayo 52 x Thatcher[2], 26 segregated 3 resistant to 1 susceptible, and 26 were susceptible, a perfect fit to the 1:1 ratio. Of 60 families of Mayo 54 x Thatcher[2], 31 segregated 3 resistant to 1 susceptible, and 29 were susceptible. This is a good fit to the 1:1 ratio expected, with a P value of .70-.80. Within segregating families, the segregation of 3 resistant to 1 susceptible was observed for both sets of families as well as in the small population of Mayo 52 x Thatcher[2] tested in the greenhouse. Since both varieties were derived from

TABLE 11.—RESULTS OF SEEDLING TESTS ON F_2 FAMILIES FROM THE BACKCROSSES OF MAYO 52 AND MAYO 54 TO THATCHER FOR RACE 1a

	No. of families		Total		No. of families		Total
	Seg 3R:1S	S			Seg 3R:1S	S	
Mayo 52 x Thatcher[2]	26[1]	26	52	Mayo 54 x Thatcher[2]	31[2]	29	30
Expected (1:1)	26	26	52	Expected (1:1)	30	30	60
P	1.00			P	.70 — .80		

[1]pop. 1 671R:224S plants P for 3:1 ratio = .99 — 1.00
[2]pop. 2 49R: 19S plants P for 3:1 ratio = .50 — .70
[2]pop. 1 789R:298S plants P for 3:1 ratio = .05 — .10

a cross in which Timstein was involved and they were shown by F_2 data to have a gene in common with Lee, Gabo and Timstein, it is logical to assume that all five varieties have the same gene which is allelic to that carried by Exchange and Selkirk.

Test results of Lee, Gabo and Timstein backcross families to race 15a are reported in Table 12. Of 81 Lee x Thatcher[2] families, 37 segregated 1 resistant to 3 susceptible, and 44 were susceptible; of 39 Gabo x Thatcher[2] families 20 segregated 1 resistant to 3 susceptible and 19 were susceptible; of 46 Timstein x Thatcher[2] families 26 segregated 1 resistant to 3 susceptible, and 20 were susceptible. These gave satisfactory fits to the 1:1 ratio, with respective P values of .30-.50, .80-.90 and .30-.50. Exactly the same picture emerged for the segregation within segregating families as that with race 1a.

TABLE 12.—RESULTS OF SEEDLING TESTS ON F_2 FAMILIES FROM THE BACKCROSSES OF LEE, GABO AND TIMSTEIN TO THATCHER FOR RACE 15a

	No. of families		Total
	Seg 1R:3S	S	
Lee x Thatcher[2]	37[1]	44	81
Expected (1:1)	40.5	40.5	81
P	.30 – .50		
Timstein x Thatcher[2]	26[3]	20	46
Expected (1:1)	23	23	46
P	.30 – .50		

	No. of families		Total
	Seg 1R:3S	S	
Gabo x Thatcher[2]	20[2]	19	39
Expected (1:1)	19.5	19.5	39
P	.80 – .90		

[1]pop. 1 359R:1176S P for 1:3 ratio = .10 – .20
pop. 2 121R:52S P for 3:1 ratio = .10 – .20
[2]pop. 1 204R:637S P for 1:3 ratio = .50 – .70
pop. 2 149R:55S P for 3:1 ratio = .50 – .70
[3]pop. 1 192R:540S P for 1:3 ratio = .30 – .50
pop. 2 95R:37S P for 3:1 ratio = .30 – .50

TABLE 13.—RESULTS OF SEEDLING TESTS ON F_2 FAMILIES FROM THE BACKCROSSES OF MAYO 52 AND MAYO 54 TO THATCHER FOR RACE 15a

	No. of families		Total
	Seg 3R:1S	S	
Mayo 52 x Thatcher[2]	26[1]	27	53
Expected (1:1)	26.5	26.5	53
P	.80 – .90		

	No. of families		Total
	Seg 3R:1S	S	
Mayo 54 x Thatcher[2]	34[2]	30	64
Expected (1:1)	32	32	64
P	.50 – .70		

[1]763R:227S plants P for 3:1 ratio = .10 – .20
[2]469R:137S plants P for 3:1 ratio = .10 – .20

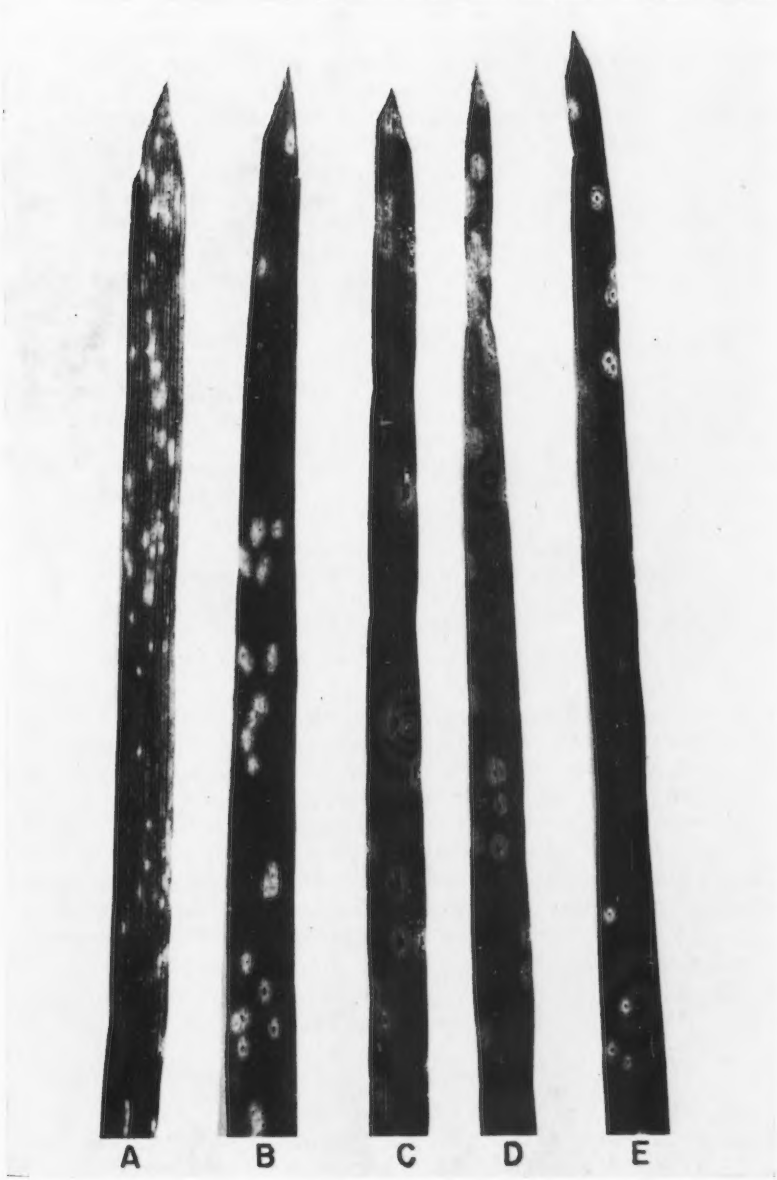

FIGURE 1. Seedling leaves showing pustule type of heterozygous and homozygous genotypes for reaction to races 1a and 15a. A. lr_E lr_E Lr_L Lr_L (homozygous Lr_L). B. lr_E lr_E Lr_L lr_L (heterozygous Lr_L). C. lr_E lr_E lr_L lr_L (susceptible). D. Lr_E lr_E lr_L lr_L (heterozygous Lr_E). E. Lr_E Lr_E lr_L lr_L (homozygous Lr_E).

The single gene present appeared to act as a recessive in the first population and as a dominant in the succeeding test. In each case where segregation occurred for race 1a, it also occurred for race 15a, the same gene conditioning a high resistance to both races as might be expected.

In Table 13 are recorded the results of tests of the backcross families of Mayo 52 and Mayo 54 to race 15a. Of the 53 Mayo x Thatcher^2 families, 26 segregated 3 resistant to 1 susceptible, and 27 were susceptible; of 64 Mayo 54 x Thatcher^2 families, 34 segregated 3 resistant to 1 susceptible, and 30 were susceptible. These gave good fits to a 1:1 ratio with P values of .80-.90 and .50-.70, respectively. This hypothesis of a single-gene difference was supported by the segregation within segregating families. Again the same families segregated for resistance to 15a as had for race 1a.

It is apparent from the foregoing data that Lee, Gabo, Timstein, Mayo 52 and Mayo 54 each have a single gene for leaf-rust resistance which is common to all five varieties. This gene, conditioning high resistance to races 1a and 15a, appears to be affected by environment when in the heterozygous state. Since the reaction is the same as that of the allelic gene for high resistance in Selkirk and Exchange these varieties probably have the same gene.

TABLE 14.—GENOTYPE OF EACH VARIETY

Exchange, Selkirk	Lr_E Lr_E	Lr_L Lr_L
Lee, Gabo, Timstein, Mayo 52, Mayo 54		Lr_L Lr_L

In Table 14 are shown the proposed genotypes of the varieties studied. The two genes have been given the symbols Lr_E and Lr_L in accordance with the recommendations of Ausemus *et al.* (2). In Table 15 the gene expression and pustule type observed on the resistant homozygote are presented. Further tests are required to evaluate whether these genes are the same or different from those already named. Genes Lr_1 to Lr_8 have been named as indicated in the literature review. Choudhuri (4) has arbitrarily named a gene from Selkirk Lr_{10}, but this cannot be accepted until tests have proven it to be different from those already named.

Figure 1 shows the pustule type of plants having the genotypes lr_E lr_E Lr_L Lr_L (A), lr_E lr_E Lr_L lr_L (B), lr_E lr_E lr_L lr_L (C), Lr_E lr_E lr_L lr_L (D) and Lr_E Lr_E lr_L lr_L (E) when tested to races 1a and 15a.

Partial Loss of Resistance to Leaf Rust in Selkirk

In 1950, the variety Lee was licensed for sale in Canada, but because of its susceptibility to loose smut was only slowly accepted. Redman, a leaf rust susceptible variety was still being grown on a wide scale. There was, therefore, little selective pressure brought to bear on the rust population and little change in the prevalent races immediately following the release of Lee.

TABLE 15.—GENE EXPRESSION IN SEEDLING PLANTS AND PUSTULE TYPE IN THE HOMOZYGOUS RESISTANT CONDITION

Gene	Race	Gene expression	Pustule type homozygous resistant condition
Lr_E	1a	Dominant, hypostatic to Lr_L	2
	15a	Dominant, hypostatic to Lr_L	2
	5a	Partially recessive (heterozygotes 3, 3+)	2
	11	Partially recessive (heterozygotes 3, 3+)	2
	126a	Partially recessive (heterozygotes 3−)	2
Lr_L	1a	Partially dominant (heterozygotes vary with conditions from 1+ without necrosis to 3)	;1 =
	15a	Partially dominant (heterozygotes vary with conditions from 1+ without necrosis to 3)	;1 =
	5a	No effect	4
	11	No effect	4
	126a	No effect	4

Figure 2 is a graphical illustration of the percentage of the Manitoba acreage sown to Lee and Selkirk and the percentage of rust collections from the spring wheat area which gave either a 4-type reaction on Lee or a moderate 2-type reaction on Selkirk during the period 1950-1958. It may be noted from Figure 2 that the collections of rust capable of attacking Lee increased as the acreage of Lee extended, reaching a high point in relation to Lee in 1954 when this variety was grown most extensively. This prepared the way for the loss of resistance provided by the same gene in Selkirk leading to a rapid increase of these Lee-attacking races as the acreage of Selkirk expanded. In the period 1956-1958 the Selkirk acreage became stabilized at about 80 per cent. This was followed by a similar stabilizing trend in the Lee-attacking races at much the same level in 1957-1958.

DISCUSSION AND CONCLUSIONS

In this investigation the number of genes for resistance to leaf rust possessed by seven varieties of common wheat as shown by their reactions to five races of leaf rust was determined. In addition, the interaction of genes and their mode of inheritance were studied. Although there is general agreement between the present work and that of other authors, certain apparent anomalies exist.

Selkirk and Exchange were found to have two genes for seedling resistance. One of these reported by Choudhuri (4) as Lr_{10} with reaction (;1=) must be the gene herein reported as Lr_L which conditions high resistance to races 1a and 15a but no resistance to race 5a. According to Choudhuri this gene confers resistance to the latter race. This apparent contradiction may be explained on the basis that the two collections of 5a used by Choudhuri and the author were in fact different races that were classed as the same race because of the failure of the differentials to distinguish between them. Such a difference does exist since collections of race 5a can be divided into two classes, one capable of attacking Lee and

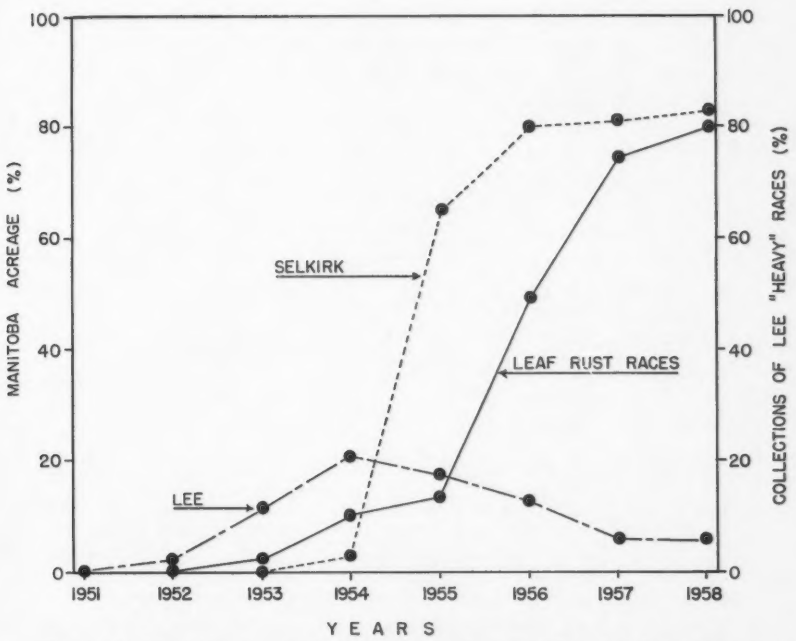

FIGURE 2. The change in leaf rust races from Lee "light" to Lee "heavy" races in response to the widespread distribution of gene Lr_L in Lee and Selkirk for the period 1951-1958. (Varietal data courtesy F. J. Greaney, Line Elevators Farm Service, Winnipeg. Leaf rust data courtesy D. J. Samborski, Canada Department of Agriculture, Winnipeg).

the other unable to attack this variety. The race used in the present paper is one from the first class and presumably the one used by Choudhuri is from the second.

A similar argument may be used to explain the fact that Levine *et al.* (12) found Gabo resistant to races 5 and 126 and Lee and Timstein resistant to races 5, 11 and 126, whereas the present study shows Gabo, Lee and Timstein to be susceptible to three biotypes of these three races.

Wu and Ausemus (20) reported that the resistance of Lee is governed by a single recessive gene for reaction to race 126 and a single dominant gene for resistance to race 5, the two factors being linked. Again, this is not in agreement with the results in this paper where Lee was shown to be susceptible to the biotypes of the races which were used. Previous studies by the author* have shown that Lee contains an additional gene for resistance to races which were not used in this study. The second gene postulated by Wu *et al.* may be this additional gene.

The work of Heyne and Johnston (8) indicates the presence of a single gene for seedling resistance in Timstein which, because of the reaction type shown, is evidently the same gene reported in this paper.

Unpublished

It was not surprising to find that Gabo, Lee, Timstein, Mayo 52 and Mayo 54 possess the same gene for resistance because of the related parentage of these varieties, each having had the same source of resistance. Similarly, it was no surprise to find that Exchange and Selkirk have the same genes for seedling resistance, since the resistance of Selkirk was derived from Exchange. It was interesting, however, to find that the latter two varieties possess the gene found in the other varieties. This gene which seems to have entered the breeding stock in Australian varieties, probably was contributed to Exchange by its Warden parent. Warden shows by its reaction to races 1a and 5a that it carries both of the seedling resistance genes of Exchange.

In the author's opinion any resistance genes which are found in a variety should be transferred by means of backcrossing to a universally susceptible variety before the full usefulness of the knowledge gained may be realized. The isogenic lines which result may have a great potential for future work. Possible uses for these lines may be listed as follows:

1. The gene may be characterized for the range of races to which it conditions resistance.
2. The single gene lines can be maintained as ideal tester stocks to determine whether a variety being genetically analysed possesses this gene or an allele.
3. Single gene lines should be particularly useful to the worker on genetics of micro-organisms to study the applicability of Flor's hypothesis (6) to the host-parasite relationship between leaf rust of wheat and its wheat host.
4. Using the isogenic lines, physiologists have an excellent tool for study of gene dosage effect. The isogenic line carries the resistance gene in the homozygous state, the recurrent parent is homozygous for susceptibility and the hybrids produced in crosses between the isogenic line and the recurrent parent carry the resistance gene in the heterozygous condition. Since all three have a common genetic background, the individual effect of the gene may be more clearly shown.
5. When sufficient numbers of backcross lines are produced, they could quite conceivably become the differential hosts of the future and because the genetics of their resistance is known, the basis of race identification should be on sounder scientific ground. This could be enlarged by combining the various resistance genes in different combinations to determine whether complementary gene action is shown.

With these thoughts in mind, isogenic lines are being developed in the wheat varieties Prelude and Thatcher, five backcrosses being made to the recurrent parents. This approach is being followed for the genes reported herein and for other genes which have not yet been reported.

The failure of a resistance gene to remain effective is exemplified by the race pattern which emerged following the release of Lee and Selkirk. Races capable of rendering the Lee gene ineffective were encountered only rarely in collections made as late as 1950. With the exposure of this resistance gene, through widespread use of Lee and Selkirk, these races rapidly increased until 80 per cent of all isolates collected in 1958 were of this type. The second gene in Selkirk conditions moderate resistance to a much wider range of races, and so far no isolates have been found in the spring wheat area which will produce more than a 2-type reaction on plants having this gene.

ACKNOWLEDGEMENTS

The author wishes to express his appreciation to D. J. Samborski, of the Canada Department of Agriculture Research Station, Winnipeg, Manitoba, for supplying the initial inoculum of the races used in this study, for the survey data on rust collections made in the period 1950-1958, and for his valuable consultation during the course of the work. The author is also indebted to W. E. Clark for the preparation of the figures, and to F. J. Greaney for the percentage Manitoba acreages of the varieties Lee and Selkirk.

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A STUDY OF THE EFFECTS OF TEMPERATURE AND OTHER FACTORS UPON THE GERMINATION OF VEGETABLE CROPS. IV. ROOT CROPS[1]

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ABSTRACT

Seeds of three varieties of each of three root crops (table beets, carrots, and rutabagas) and one bulb crop (onions) were placed in rolled-towel seed testers and subjected to controlled temperatures (35°, 40°, 45°, and 50°F.) for periods up to 22 days, and then transferred to a warm room for completion of germination. Significant differences in germination between varieties were noted for each crop. Table beets and onions were not appreciably affected by temperature treatment, but carrot germination was significantly reduced by temperatures below 50°F., and rutabaga germination was similarly reduced at 35°F. Only table beet germination was significantly altered by duration of exposure where germination increased after 8 and 15 days. There was a fairly well defined pattern in the effects of the interaction between temperature and duration of exposure. In most instances, maximum germination was obtained after 15 days' exposure and minimum germination was associated with 1 or 8 days' exposure, within a temperature treatment. Varietal interactions with temperature and duration of exposure indicated that genetical constitution may not be as important a factor in germination as suggested by other workers.

INTRODUCTION

The root vegetables have been grown as economic crops in southern Alberta for many years although the acreage involved has not been large. Table beets (*Beta vulgaris* L.) and carrots (*Daucus carota* L. var. sativa DC) are grown for processing, as well as for the fresh trade. Rutabagas (*Brassica napobrassica* Mill.) are grown for local consumption and for export. In the past, the onion (*Allium cepa* L.) has been a problem, because it would not mature from seed in the short season that prevails. However, many of the newer hybrid onions will mature, and there has been a renewed interest in the production of this vegetable. The onion, a bulb, is included in the broad definition of root crop for the purpose of this study.

The root vegetables, as a group, are usually seeded as early as soil conditions will permit. Consequently, the seed may be subjected to an extended period of low soil temperature. There is little reference, in the literature, to the minimum temperatures at which these crops will germinate. Thompson (2) and Work (6) stated that the root crops are hardy and may be planted as soon as the danger of hard, killing frosts is past.

Kotowski (1) concluded, on the basis of trials under controlled temperatures, that no seedlings of beets, carrots, onions, or cabbage (rutabagas were not included) emerged during exposure to 39°F. He noted, further, that radicles of beets, carrots, and cabbage grew at this temperature but that hypocotyl growth was checked or inhibited. These vegetables germinated after transfer to 86°F. for 1 or 2 days, but no mention was made of the proportion of seedlings obtained. Kotowski lists the optimal temperatures for germination as follows: beet–52°F.; carrot–46° to 64°F.; onion–64°F.; and cabbage–46°F.

[1]Contribution from the Horticulture Section.

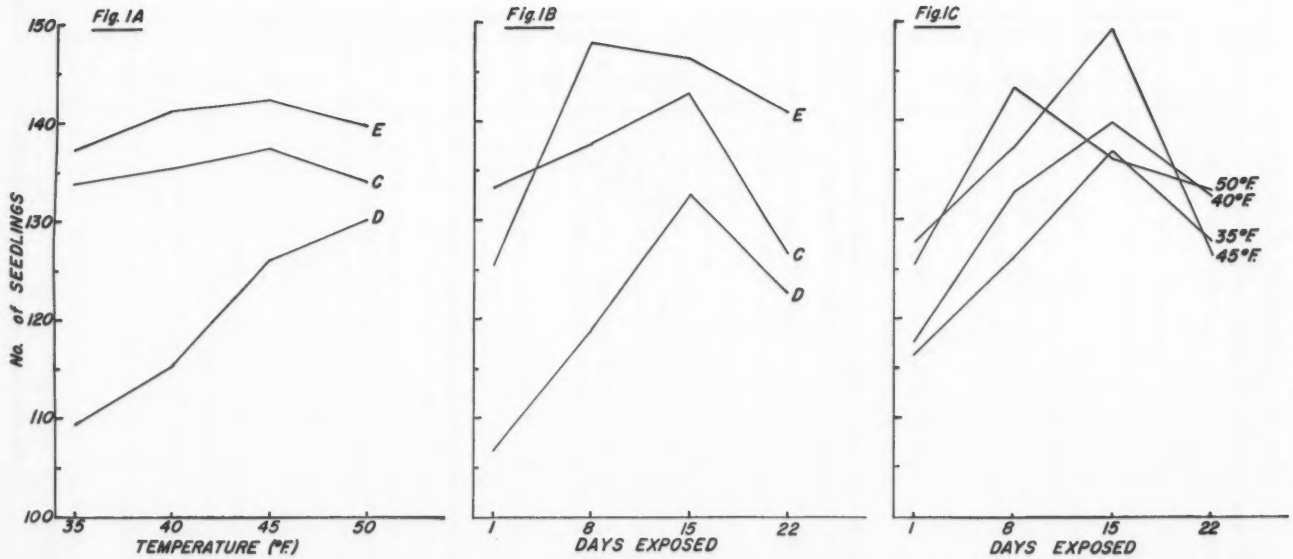

FIGURE 1. The effects of various interactions upon the germination of table beets: (A) variety x temperature; (B) variety x duration of exposure; and (C) temperature x duration of exposure. (Variety code: D — Detroit Dark Red; C — Crosby's Egyptian; E — Early Wonder).

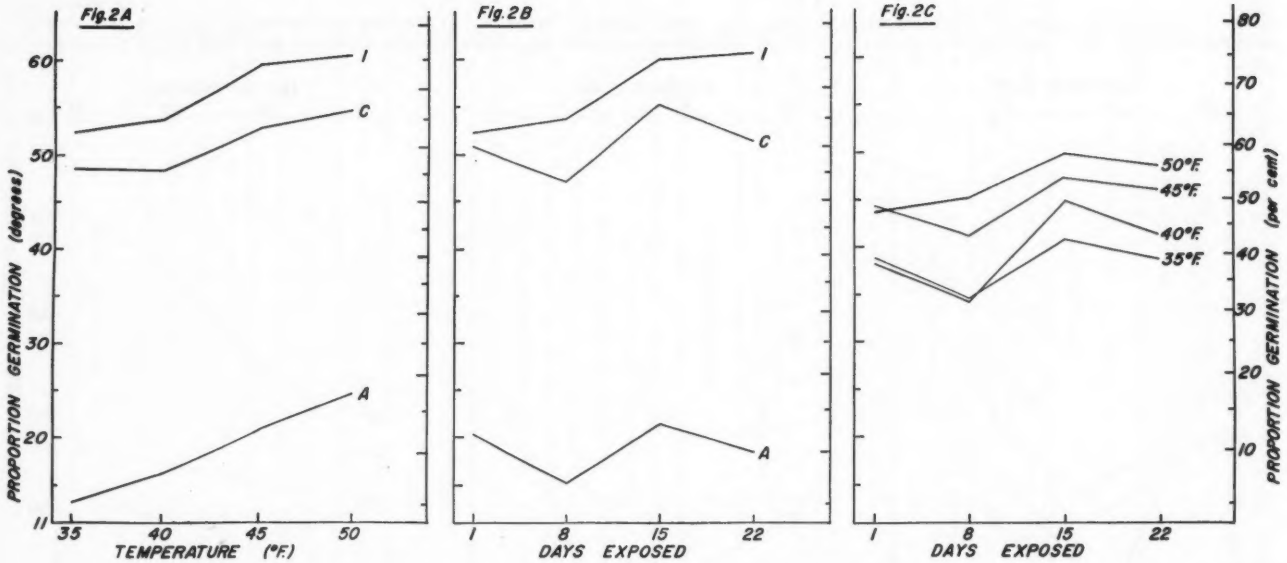

FIGURE 2. The effects of various interactions upon the germination of carrots: (A) variety x temperature; (B) variety x duration of exposure; (C) temperature x duration of exposure. (Variety code: C — Red Chantenay; A — Amsterdam; I — Imperator).

Previous studies have shown that germination of sweet corn (3) was seriously inhibited by temperatures below 50°F., and that melons (5) will germinate satisfactorily after exposure to temperatures well below the accepted minima. Exposure to 45° and 50°F. for 22 days resulted in stimulation of germination over that obtained for 15 days. Germination of a cool season crop, peas, (4) was apparently stimulated by long exposure to low temperatures.

This is the fourth and final paper of this series and presents the effects of various durations of exposure to different temperatures upon germination of root crops. The four crops studied represent four separate plant families, i.e., table beets—Chenopodiaceae; carrots—Umbelliferae, rutabagas—Cruciferae; and onions—Liliaceae.

MATERIALS AND METHODS

The following variables were considered:

1. *Temperature*: Controlled temperature chambers were maintained at 35°, 40°, 45°, and 50°F. throughout the study.
2. *Duration of Exposure*: The seed was exposed to each of the above temperatures for periods of 1, 8, 15, and 22 days.
3. *Crops and Varieties*: The following kinds and varieties were subjected to all combinations of temperature and duration of exposure:
   Table Beet — Detroit Dark Red, Crosby's Egyptian, and Early Wonder
   Carrot — Red Chantenay, Amsterdam, and Imperator
   Onion — Southport Yellow Globe, Hybrid Yellow Globe Y41, and Hybrid Sweet Spanish
   Rutabaga — Laurentian, American Purple Top, and Cannell's Purple Top.
   The first variety, in each group, was used as the standard for comparison.
4. *Sampling*: All treatments were sampled four times.

The rolled-towel seed tester technique (5) was used and the paper towels were moistened with water containing fungicide (Fermate) to reduce fungal activity.

Each crop, i.e., table beets, carrots, onions, or rutabagas, constituted a separate trial. A trial contained four plots representing the four temperatures and each of these plots consisted of 12 randomly arranged sub-plots, representing all combinations of the three varieties and the four durations of exposure. Each sub-plot consisted of 400 seeds. Observations were made on four samples of each subplot.

The rolled-towels were placed in plastic bags and kept in the controlled temperature chambers for the specified exposure periods. It was desirable to have all treatments completed at the same time, so the seedings were spaced accordingly. After treatment, all containers were moved to a warm room (approximately 70°F.), and a final count of seedlings was made 15 days later.

Germination of carrots, rutabagas, and onions was recorded as the percentage of healthy seedlings and transformed for statistical analysis using the angular transformation as in previous trials (3, 4, 5). These data are

presented as angular degrees and as percentages, with the least significant differences presented in degrees only. Table beet germination was recorded as the total number of healthy seedlings from 100 multiple-embryo seeds. These data were not transformed. Analysis of variance was used to determine significant differences.

EXPERIMENTAL RESULTS

At the conclusion of the exposure periods, examination revealed that samples of all four crops exposed to 45° and 50°F. for more than 8 days had produced a high proportion of healthy seedlings. Samples exposed for 1 day showed no visible development and other treatment combinations resulted in radicle development but little hypocotyl growth.

Beets

Analysis of the germination data showed that significant differences occurred between varieties and between durations of exposure. As shown in Table 1A, Crosby's Egyptian and Early Wonder produced significantly greater numbers of seedlings than Detroit Dark Red. Significant increases in the number of seedlings occurred when periods of exposure were lengthened from 1, to 8, to 15 days (Table 1C). Exposure for 22 days, however, resulted in a reduction in seedling number. There were no real differences between temperature treatments (Table 1B).

The number of seedlings of the different varieties, was significantly altered by temperature (Figure 1A). The varieties, Crosby's Egyptian and Early Wonder, showed little temperature effect with greatest germination at 45°F. On the other hand, Detroit Dark Red showed a marked and regular increase in seedling number as the temperature was raised from 35° to 50°F.

The duration of exposure also affected germination in the three varieties (Figure 1B). Crosby's Egyptian and Detroit Dark Red produced maximum numbers of seedlings after 15 days of exposure while Early Wonder did so after 8 days. Early Wonder and Detroit Dark Red had minimum seedling numbers after 1 day of exposure, and Crosby's Egyptian after 22 days. The

TABLE 1.—MEAN NUMBERS OF TABLE BEET SEEDLINGS AS AFFECTED BY: (A) VARIETY; (B) TEMPERATURE; AND (C) DURATION OF EXPOSURE

A		B		C	
Variety	No. of seedlings	Temperature °F.	No. of seedlings	Days exposed	No. of seedlings
Detroit Dark Red	120.2	35	126.8	1	121.8
Crosby's Egyptian	135.1[1]	40	130.6	8	134.9[2]
Early Wonder	140.1[1]	45	135.3	15	140.5[2]
		50	134.5	22	130.0
L.S.D. (0.05)	±6.1	L.S.D. (0.05)	n.s.	L.S.D. (0.05)	±11.4

[1]Differs significantly from germination of Detroit Dark Red
[2]Differs significantly from germination after the 1-day exposure

TABLE 2.—MEAN GERMINATION OF CARROTS (IN DEGREES) AS AFFECTED BY: (A) VARIETY; (B) TEMPERATURE; AND (C) DURATION OF EXPOSURE

A		B		C	
Variety	Mean germination	Temperature °F.	Mean germination	Days exposed	Mean germination
Red Chantenay	51.1 (60.6)[4]	35	38.0[2] (37.9)[4]	1	41.2 (43.4)[4]
Amsterdam	18.8[1] (10.4)	40	39.5[2] (40.5)	8	38.6 (39.0)
Imperator	56.5[1] (69.7)	45	44.5[2] (49.2)	15	45.4[3] (50.7)
		50	46.6 (52.8)	22	43.3[3] (47.1)
L.S.D. (0.05)	±2.1	L.S.D. (0.05)	±1.8	L.S.D. (0.05)	±4.6

[1]Differs significantly from germination of Red Chantenay
[2]Differs significantly from germination at 50° F.
[3]Differs significantly from germination after 8 days of exposure
[4]Per cent germination in parentheses

effects of temperature upon germination were modified by duration of exposure, as shown in Figure 1C. At 50°F., maximum seedling numbers were obtained after 8 days of exposure and the numbers decreased with longer exposure periods. At the other temperatures, the maximum numbers of seedlings were obtained after 15 days of exposure followed by a decrease after 22 days. This decrease was more marked at 45°F. than at either 40° or 35°F.

Carrots

In the carrot trial, differences between varieties, between temperatures, and between durations of exposure were found to be significant. Mean germination of the varieties is shown in Table 2A. The proportion of seedlings of both Amsterdam and Imperator differed significantly from that of Red Chantenay. The low germination of Amsterdam may have been caused by a predominance of very small seed. The effect of temperature (Table 2B) shows that germination at 45°F., or less, was significantly lower than at 50°F. The effects of duration of exposure are shown in Table 2C. Applying the L.S.D., it was found that germination at 15 and 22 days differed significantly from the 8-day exposure.

The effects of the first order interactions are illustrated in Figure 2. It should be noted that only one of these was statistically significant. Duration of exposure differentially affected the germination of the different varieties (Figure 2B). Red Chantenay and Amsterdam show almost identical trends, while Imperator shows deviations at the intervals of 1 to 8 days and 15 to 22 days. The temperature x variety (Figure 2A) and the temperature x duration of exposure (Figure 2C) interactions were not significant.

Rutabagas

Analysis of the rutabaga germination data revealed significant differences due to variety and temperature but not due to duration of exposure.

FIGURE 3. The effects of various interactions upon the germination of rutabagas: (A) variety x temperature; (B) variety x duration of exposure; (C) temperature x duration of exposure. (Variety code: L – Laurentian; A – American Purple Top; C – Cannell's Purple Top).

TABLE 3.—MEAN GERMINATION OF RUTABAGAS (IN DEGREES) AS AFFECTED BY: (A) VARIETY; (B) TEMPERATURE; AND (C) DURATION OF EXPOSURE

A		B		C	
Variety	Mean germination	Temperature °F.	Mean germination	Days exposed	Mean germination
Laurentian	43.6 (47.8)[3]	35	43.3[2](47.1)[3]	1	48.0 (55.2)[3]
American Purple Top	84.7[1] (99.1)	40	51.1 (60.6)	8	48.3 (55.8)
		45	51.5 (61.3)	15	53.0 (63.8)
Cannell's Purple Top	21.9[1] (13.9)	50	54.3 (66.0)	22	51.0 (60.4)
L.S.D. (0.05)	±2.1	L.S.D. (0.05)	±8.3	L.S.D. (0.05)	n.s.

[1]Differs significantly from germination of Laurentian
[2]Differs significantly from germination at 50° F.
[3]Per cent germination in parentheses

Mean germination, as presented in Table 3A, shows that American Purple Top produced a significantly higher proportion of seedlings and Cannell's Purple Top significantly lower proportion than Laurentian. Table 3B shows that there was no real treatment difference between 50°F. and either 45° or 40°F., while germination at 35°F. was significantly lower. Although there was a trend for a higher proportion of seedlings at longer durations of exposure, there were no significant differences (Table 3C).

The significance of temperature effects upon germination of varieties is illustrated in Figure 3A. Germination of American Purple Top was not affected by temperature. The other varieties showed decreased seedling proportions at 35°F., and slight increases at 50°F.

The effect of duration of exposure upon germination at the different temperatures was variable. This is shown in Figure 3C. Germination at 45°F. was least affected by duration of exposure with only a slight decrease after 8 days of exposure; at 35°F., an increase was recorded as exposure periods lengthened; at 50°F., an increase was recorded up to 15 days and a decrease at 22 days; and at 40°F., a sharp increase was noted as exposure increased from 8 to 15 days followed by a slight decrease at 22 days.

Onions

When exposure periods were completed, germination of onion seed exposed to 45° and 50°F. for 8, 15, and 22 days was virtually complete. Analysis of the data showed that there were significant differences between varieties, as illustrated in Table 4A. It may be seen that all varieties germinated exceptionally well and that Hybrid Yellow Globe Y41 and Hybrid Sweet Spanish produced a significantly lower proportion of seedlings than Southport Yellow Globe. Temperature and duration of exposure effects are presented in Tables 4B and 4C, respectively. There were no significant differences due to these variables.

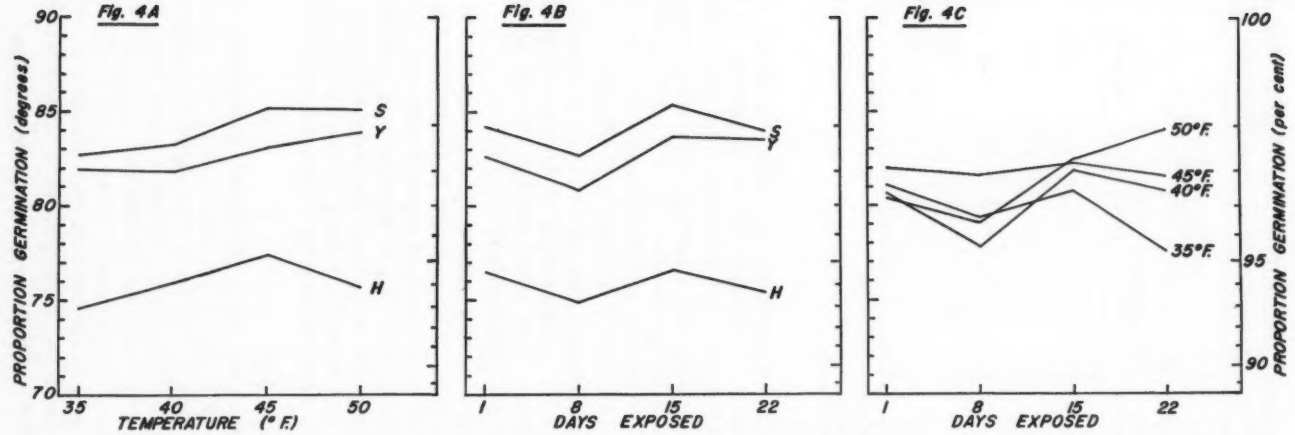

FIGURE 4. The effects of various interactions upon the germination of onions: (A) variety x temperature; (B) variety x duration of exposure; (C) temperature x duration of exposure. (Variety code: S — Southport Yellow Globe; Y — Hybrid Yellow Globe Y41; H — Hybrid Sweet Spanish).

TABLE 4.—MEAN GERMINATION OF ONIONS (IN DEGREES) AS AFFECTED BY: (A) VARIETY; (B) TEMPERATURE; AND (C) DURATION OF EXPOSURE

A		B		C	
Variety	Mean germination	Temperature °F.	Mean germination	Days exposed	Mean germination.
Southport Yellow Globe	84.1 (98.9)[2]	35	79.7 (96.8)[2]	1	81.1 (97.6)[2]
		40	80.3 (97.2)	8	79.5 (96.7)
Hybrid Yellow Globe Y41	82.7[1] (98.4)	45	81.9 (98.0)	15	81.9 (98.0)
Hybrid Sweet Spanish	75.9[1] (94.1)	50	81.5 (97.8)	22	81.0 (97.5)
L.S.D. (0.05)	±1.2	L.S.D. (0.05) n.s.		L.S.D. (0.05) n.s.	

[1]Differs significantly from germination of Southport Yellow Globe
[2]Per cent germination in parentheses

Germination of varieties was not significantly affected by temperature treatment (Figure 4A) or by duration of exposure (Figure 4B). However, temperature effects were altered by duration of exposure (Figure 4C). At 45°F., the proportion of seedlings was not affected by exposure time while, at the other temperatures, decreases after 8 days of exposure and increases after 15 days were observed. After 22 days of exposure, slight increases were obtained at 50°F. and decreases at 35° and 40°F.

DISCUSSIONS AND CONCLUSIONS

Although the root crops studied belong to four different families, there are certain similarities in their response to the various treatments. For example, all crops produced the highest proportion of seedlings at 45° or 50°F. While exposed to the lower temperatures, germination was restricted to radicle development, confirming Kotowski's observations (1). However, after removal to room temperature, normal seedlings developed and the numbers of seedlings were only slightly lower than at the higher temperatures. Onions and table beets were less affected by temperature treatments than were carrots or rutabagas. The general increase in germination with increased temperature was similar to that recorded for peas in a previous study (4). Germination of sweet corn (3) and the vine crops (5) followed similar trends although different temperature ranges were used.

All four crops produced the highest proportion of seedlings after 15 days of exposure followed by a decrease after 22 days. This decrease was most pronounced in table beets and appeared to be associated with an increase in mould growth. These effects (up to 15 days' exposure) were similar to those recorded for peas (4), but were opposite to the effects on vine crops (5) where germination decreased as exposure was prolonged to 15 days, followed by an increase after 22 days. Sweet corn germination decreased progressively as the exposure period was lengthened (3).

Seed lots of the varieties differed in their ability to germinate, but were similarly affected by temperature and by duration of exposure in most crops. Slight deviations were noted in the table beet and rutabaga trials. Sweet corn (3) and peas (4) followed the same general trends, but the vegetable vine crops (5) were more variable and inconsistent. It would seem, therefore, that varieties of most crops react similarly to temperature treatment, indicating that the genetical constitution may not be as important a factor in germination as suggested by Haskell (3). Significant differences due to the interaction of temperature and duration of exposure, in three of the four crops, were not comparable from one crop to the other, except that highest germination, at most temperatures, was obtained after 15 days' exposure, and that the variations in each case fell within a relatively narrow range. Onions germinated in excess of 95 per cent after 22 days at 35°F., and it is probable that the lower limit of cold tolerance for this crop had not been attained. Contrary to the observations of Thompson (2) and Work (6), it is apparent that onions may be seeded as early as a seed bed can be prepared, regardless of soil temperature or danger of hard frosts. It is concluded that most root crops will germinate satisfactorily after relatively long exposure to temperatures as low as 35°F.

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THE PEDIGREE OF VARIETIES OF *LYCOPERSICON ESCULENTUM* MILL.[1]

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ABSTRACT

A tomato pedigree chart was prepared 1) to show varieties primarily of historical significance in current breeding programs, and 2) to emphasize the early-maturing determinate varieties used in the breeding programs of the Prairie region of Western Canada. These charts have been prepared not as a final word but rather as an introduction, and to encourage others interested in developing tomato pedigrees.

A great many varieties of tomato, *Lycopersicon esculentum* Mill., have been introduced in North America during the last century. Many survived only a few years while others, such as Earliana and Ponderosa, are still relatively well known after 60 or more years. During the early years of tomato improvement few records were kept of the parentage or other background material that might shed some light on the origin of a variety. Despite the obscure background of many of the earlier varieties a chart portraying the known pedigree of the more common varieties today would be of considerable value. Along these lines Graham (10) has charted the varietal origin of a number of the important hereditary characters. However, the full development of the pedigrees would be useful to perfect a new variety for specific needs, particularly in breeding programs which introduce a complexity of parents. An attempt has been made to prepare such a pedigree chart drawn largely from the vegetable lists compiled by the American Society for Horticultural Science (1, 2, 3, 4, 5), Boswell (8), and Morrison (14).

From the outset it was recognized that a functional chart showing the complete known pedigrees of all tomato varieties would not be feasible. However, a chart was developed 1), to show varieties primarily of historical significance in current breeding programs, and 2), to emphasize the early-maturing determinate varieties used in the breeding programs of the Prairie region of Western Canada.

An examination of the charts (Figures 1 and 2) reveals that crosses with varieties Earliana and Marglobe are connected by broken lines. This was found desirable to conserve space and to eliminate a multitude of connecting lines, which would have been confusing. The progeny arising from a cross involving either Marglobe or Earliana may best be determined by following the horizontal broken line from the other parent to the solid vertical line dropping from the broken line to the resulting variety. In the case of a three-way cross that includes either Marglobe or Earliana the third parent is connected to the horizontal broken line by a solid vertical line, e.g., Danmark x Marglobe are connected by a broken line, and the vertical line dropping down connects with Victor, from which a second vertical line

[1]Contribution from the Horticulture Section, Canada Department of Agriculture Research Station, Lethbridge, Alta.

FIG. I. PEDIGREE OF VARIETIES OF *Lycopersicon esculentum*

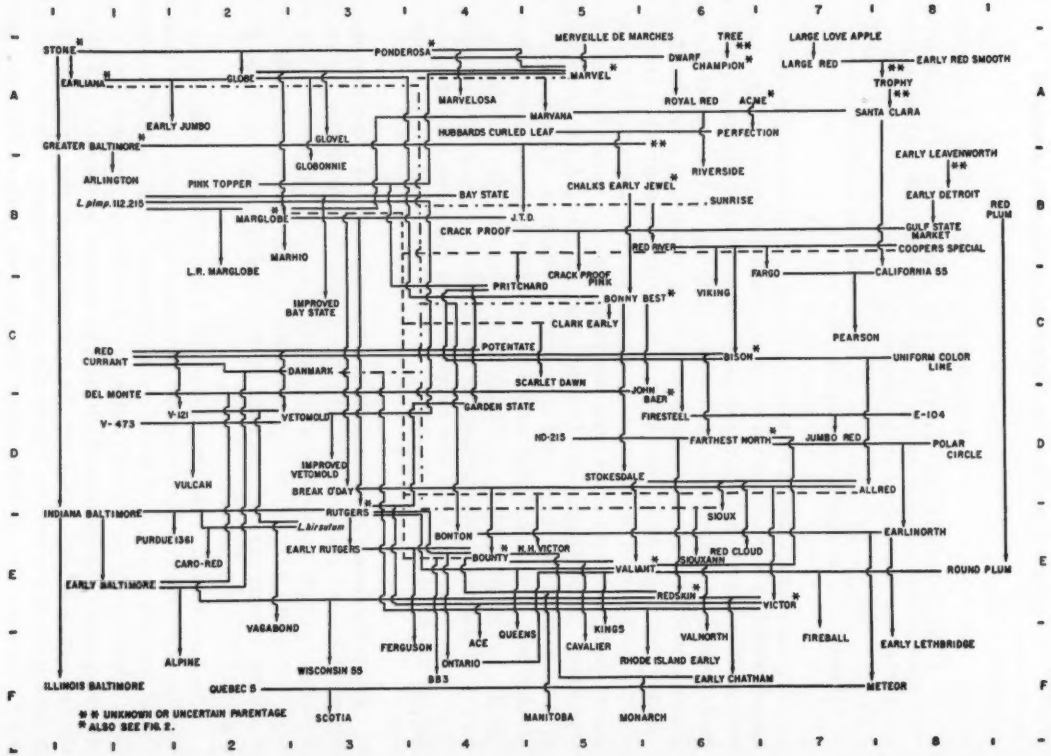

FIG. 2. PEDIGREE OF VARIETIES OF *Lycopersicon esculentum*

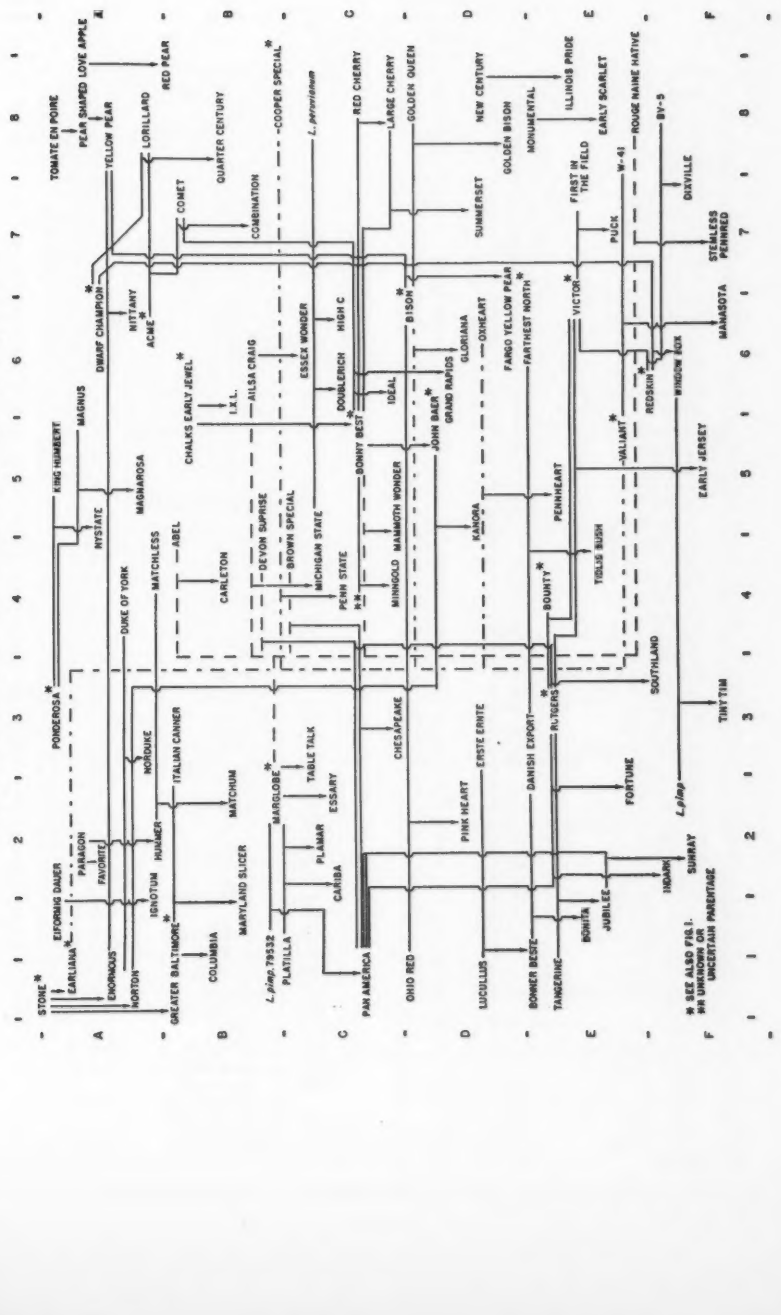

TABLE 1. — TOMATO VARIETIES LISTED ALPHABETICALLY TO SHOW THEIR REFERENCE POINT IN FIGURES 1 AND 2 AND TO INDICATE THE REFERENCE CITED

	Figure reference	Bibliography reference
1. Abel	2-B-4	1
2. Ace	1-F-4	3
3. Acme	1-A-6	8
4. Ailsa Craig	2-B-6	14
5. Allred	1-D-7	3
6. Alpine	1-F-1	1
7. Arlington	1-B-1	8
8. Bay State	1-B-4	1
9. BB3	1-F-4	17
10. Bison	1-C-6	19
11. Bonita	2-E-1	13
12. Bonner Beste	2-E-1	13
13. Bonny Best	1-C-5	8
14. Bonton	1-E-4	?
15. Bounty	1-E-4	1
16. Break O'Day	1-D-3	8
17. Brown Special	2-C-4	1
18. BV-5	2-F-8	2
19. California 55	1-C-8	8
20. Carleton	2-B-4	1
21. Cariba	2-C-2	1
22. Caro Red	1-E-1	5
23. Cavalier	1-F-5	1
24. Chalk Early Jewel	1-B-5	14
25. Chesapeake	2-C-3	1
26. Clark Early	1-C-5	8
27. Columbia	2-B-1	8
28. Combination	2-B-7	8
29. Comet	2-B-7	8
30. Coopers Special	1-B-8	8
31. Crack Proof	1-B-4	3
32. Crackproof Pink	1-B-5	4
33. Danish Export	2-E-2	13
34. Danmark	1-C-3	1
35. Del Monte	1-D-1	2
36. Devon Surprise	2-C-4	1
37. Dixville	2-F-7	2
38. Doublerich	2-C-6	1
39. Duke of York	2-A-4	14
40. Dwarf Champion	1-A-6	14
41. E-104	1-D-8	3
42. Earliana	1-A-1	8
43. Earlinorth	1-E-8	3
44. Early Baltimore	1-E-1	14
45. Early Chatham	1-F-6	2
46. Early Detroit	1-B-8	8
47. Early Jersey	2-F-5	3
48. Early Jumbo	1-D-7	19
49. Early Lethbridge	1-F-8	3
50. Early Leavenworth	1-A-8	14
51. Early Red Smooth	1-A-8	14
52. Early Rutgers	1-E-3	?
53. Early Scarlet	2-E-8	1
54. Eiformig Dauer	2-A-1	8
55. Enormous	2-A-1	14
56. Erste Ernte	2-D-3	13
57. Essary	2-C-2	1
58. Essex Wonder	2-C-6	7
59. Fargo	1-C-7	19
60. Fargo Yellow Pear	2-D-6	19
61. Farthest North	1-D-6	19
62. Favorite	2-A-1	13
63. Ferguson	1-F-3	3
64. Fireball	1-F-7	3
65. Firesteel	1-D-6	12
66. First in the Field	2-E-7	?
67. Fortune	2-E-2	2
68. Garden State	1-D-4	3
69. Globe	1-A-2	8
70. Globonnie	1-B-3	6
71. Gloriana	2-D-6	3
72. Glovel	1-A-3	8
73. Golden Bison	2-D-8	19
74. Golden Queen	2-D-8	19
75. Grand Rapids	2-D-6	8
76. Greater Baltimore	1-A-1	8
77. Gulf State Market	1-B-8	8
78. High C	2-C-6	20
79. Hubbards Curled Leaf	1-A-4	14
80. Hummer	2-A-2	8
81. Ideal	2-C-6	14
82. Ignotum	2-A-1	8
83. Illinois Baltimore	1-F-1	8
84. Illinois Pride	2-E-8	14
85. Improved Bay State	1-C-3	1
86. Improved Vetomold	1-D-3	16
87. Indark	2-F-2	2
88. Indiana Baltimore	1-D-1	8
89. Italian Canner	2-B-3	8
90. I. X. L.	2-B-6	14
91. John Baer	1-D-6	8
92. J. T. D.	1-B-4	14
93. Jubilee	2-E-1	3
94. Jumbo Red	1-D-7	3
95. Kanora	2-D-5	14
96. King Humbert	2-A-5	14
97. Kings	1-F-5	3
98. Large Cherry	2-C-8	18
99. Large Love Apple	2-A-8	14
100. Large Red	2-A-8	14
101. Lorrillard	2-A-8	2
102. L. R. Marglobe	1-B-2	16
103. Lucullus	2-D-1	13
104. L. hirsutum	1-E-3	2
105. L. peruvianum	2-C-8	1
106. L. pimpinellifolium 112.215	1-B-1	1
107. L. pimpinellifolium 79532	2-B-1	2

TABLE 1. — (*Continued*)

	Figure reference	Bibliography reference
108. L. pimpinellifolium	2-F-2	2
109. Magnus	2-A-5	14
110. Magnarosa	2-A-5	14
111. Mammoth Wonder	2-C-5	3
112. Manasota	2-F-6	3
113. Manitoba	1-F-5	3
114. Marglobe	1-B-2	8
115. Marhio	1-B-2	8
116. Marvana	1-A-5	8
117. Marvel	1-A-5	8
118. Marvelosa	1-A-4	8
119. Maryland Slicer	2-B-1	8
120. Matchless	2-A-4	14
121. Matchum	2-B-2	8
122. Merveille de Marches	1-A-5	8
123. Meteor	1-F-7	2
124. Michigan State	2-C-4	8
125. Minngold	2-C-4	2
126. Monarch	1-F-6	17
127. Monumental	2-E-8	1
128. ND 215	1-D-5	15
129. New Century	2-D-8	14
130. New Hampshire Victor	1-E-4	2
131. Nittany	2-A-6	8
132. Norduke	2-A-3	8
133. Norton	2-A-1	14
134. Nystate	2-A-4	8
135. Ohio Red	2-D-1	14
136. Ontario	1-F-4	3
137. Oxheart	2-D-6	14
138. Pan America	2-C-1	2
139. Paragon	2-A-2	8
140. Pear Shaped Love Apple	2-A-8	14
141. Pearson	1-C-7	8
142. Pennheart	2-E-5	2
143. Penn. State	2-C-4	8
144. Perfection	1-A-6	14
145. Pink Heart	2-D-2	19
146. Pink Topper	1-B-2	3
147. Plamar	2-C-2	9
148. Platillo	2-C-1	9
149. Polar Circle	1-D-8	3
150. Ponderosa	1-A-3	8
151. Potentate	1-C-4	1
152. Pritchard	1-C-4	8
153. Puck	2-E-7	?
154. Purdue 1361	1-E-1	1
155. Quarter Century	2-B-8	8
156. Quebec 5	1-F-2	4
157. Queens	1-F-4	1
158. Red Cherry	2-C-8	18
159. Red Cloud	1-E-6	2
160. Red Currant	1-C-1	19
161. Red Pear	2-B-8	14
162. Red Plum	1-B-8	14
163. Red River	1-B-6	19
164. Redskin	1-E-6	15
165. Rhode Is. Early	1-F-5	5
166. Riverside	1-B-6	1
167. Rouge Naine Hative	2-E-8	2
168. Round Plum	1-E-8	3
169. Royal Red	1-A-6	8
170. Rutgers	1-E-3	8
171. Santa Clara	1-A-7	8
172. Scarlet Dawn	1-C-4	14
173. Scotia	1-F-3	4
174. Sioux	1-E-6	2
175. Siouxann	1-E-6	2
176. Southland	2-F-3	1
177. Stemless Pennred	2-F-7	2
178. Stokesdale	1-D-5	4
179. Stone	1-A-1	8
180. Summerset	2-D-7	18
181. Sunray	2-F-2	2
182. Sunrise	1-B-6	19
183. Table Talk	2-C-3	3
184. Tidlig Bush	2-E-4	13
185. Tiny Tim	2-F-3	2
186. Tomate en Poire	2-A-8	14
187. Tree	1-A-6	14
188. Trophy	1-A-8	8
189. Uniform Color Line	1-C-8	19
190. V-121	1-D-1	1
191. V-473	1-D-1	1
192. Vagabond	1-E-2	2
193. Valiant	1-E-5	4
194. Valnorth	1-F-6	1
195. Vetomold	1-D-2	1
196. Victor	1-E-7	1
197. Viking	1-C-6	19
198. Vulcan	1-D-2	1
199. W-41	2-E-8	3
200. Window Box	2-F-6	1
201. Wisconsin 55	1-F-3	2
202. Yellow Pear	2-A-8	19

indicates the resulting variety Rhode Island Early. A number of varieties are common to both Figures 1 and 2, thus tying the two charts together. Crosses are indicated by vertical lines running from the offspring to a horizontal line connecting the parents and selections by a vertical line from the parent variety. For example, the variety Early Lethbridge was a selection from Earlinorth, which resulted from a cross of Farthest North x Polar Circle, the latter of unknown parentage. Farthest North is from a cross of Bison x Red Currant, Bison from Red River x Coopers Special, and Red River from Sunrise x Earliana. Sunrise is of unknown origin. Many other varieties such as Early Lethbridge are not far removed from Earliana but differ in characters that have been selected from intervening parents.

In Table 1 all varieties are listed in alphabetical order, together with a position reference in Figures 1 and 2, e.g., Abel 2-B-4 is shown in Row B, Column 4 of Figure 2. In addition, in all but a few varieties, the reference source is given in the next column.

These tomato pedigree charts are submitted not as a final word on this subject, but rather as an introduction to a system of charting pedigrees and as possible encouragement to others interested in this problem to develop more complete charts.

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NON-ENZYMATIC BROWNING IN CAULIFLOWER[1]

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ABSTRACT

In a study of local cauliflower discoloration it was found that added l-ascorbic acid markedly increased the pink colour formed on heating. The pink colour formation is relatively slow, takes place regardless of the inherent ascorbic acid content, and appears to be due to a non-enzymatic browning reaction.

INTRODUCTION

The non-enzymatic browning of plant tissue generally is considered to be due to the formation of melanonic compounds by condensation of such plant constituents as amino acids, carboxylic acids, simple sugars, and ascorbic acid (1, 2). Reactions of this type have been reported to occur in a variety of foodstuffs but usually in those that have had at least part of the original moisture removed or that were by nature low in moisture.

[1]Contribution from the Horticulture Section, Research Station.

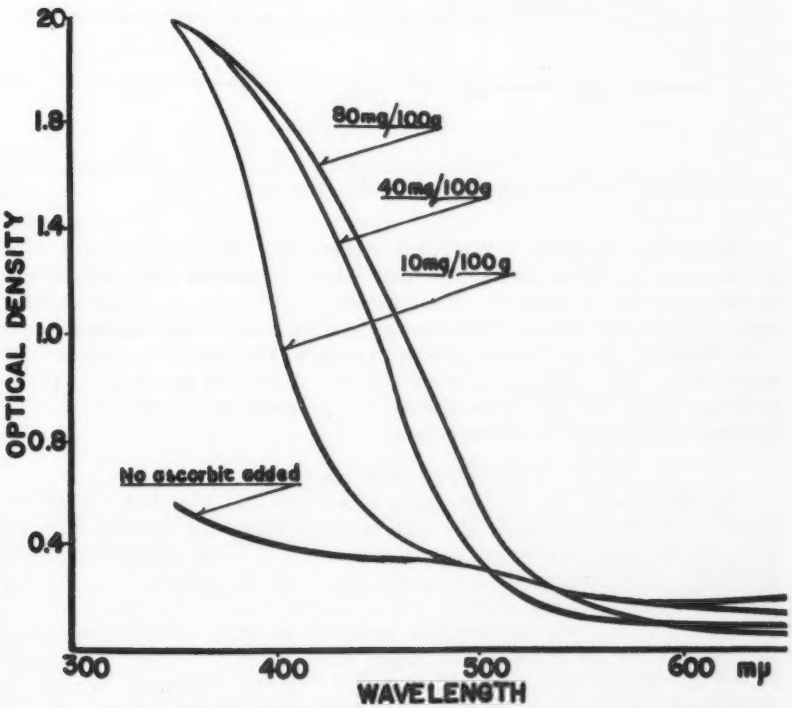

Figure 1. The influence of added l-ascorbic acid on the optical properties of cauliflower extracts.

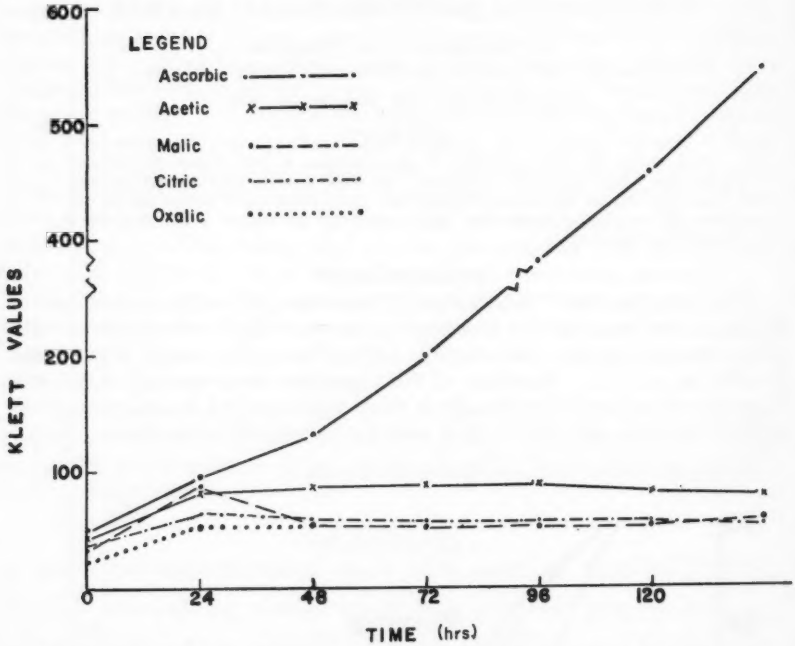

FIGURE 2. The effect of time and added organic acids on colour development measured at 420 mμ (Klett filter No. 42) in cauliflower extracts.

While investigating a suspected anthocyanin discoloration of locally grown cauliflower, it was found that added l-ascorbic acid enhanced a secondary colour formation. The increase of colour due to added ascorbic acid was such that the curd became bright pink at high acid concentrations. This discoloration occurred without regard to the inherent ascorbic acid of the cauliflower, which may be as high as 120 mg./100 gm. in the varieties grown. Apparently the pink colour is an illusion, as extracts of the discoloured curd have a brownish colour.

METHODS AND RESULTS

Samples, consisting of 300 grams of cleaned and blanched cauliflower florets, were placed in sterile jars with an equal volume of aqueous solutions of l-ascorbic acid, ranging in concentration from 0 to 80 milligrams per 100 millilitres. The jars and their contents were heated to inactivate interfering enzyme systems*, cooled, and allowed to stand at room temperature. Within 24 hours a faint pink discoloration appeared in those samples containing 50 mg./100 gm. or more of l-ascorbic acid. After 72 hours all samples except the blanks were coloured in varied degrees. Attempts to measure the surface colour failed due to the non-uniformity of the surface. Macer-

*Strachan, G. *Unpublished results.*

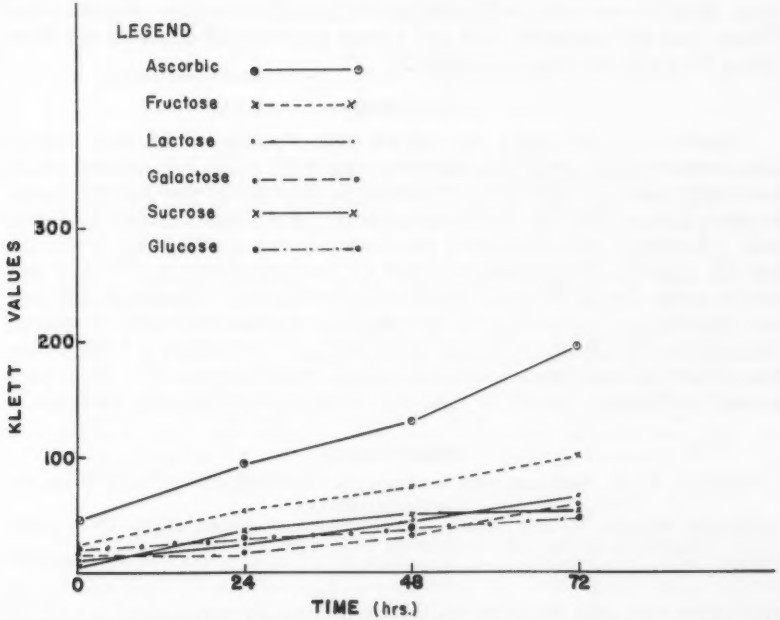

FIGURE 3. The effect of time, added l-ascorbic and sugars on colour development measured at 420mμ (Klett filter No. 42) in cauliflower extracts.

ation of the tissue dispersed the pink colour to such an extent that reflectometer evaluation could not be made. Spectrophotometric examination of liquid extracts showed an optical maxima at about 400 mμ (Figure 1). These extracts also gave an intense blue fluorescence when exposed to ultra-violet light.

Cauliflower curd that had been boiled for 6 minutes to inactivate polyphenolases* was macerated with an equal weight of distilled water. The resulting slurry was cleared by centrifuging and filtering. Aliquots of from 0 to 9 millilitres of the resulting extract were placed in calibrated Klett colorimetric tubes and sufficient 0.1 M aqueous l-ascorbic acid was added to make the total volume 10 millilitres. The tubes were stoppered and held at 60°C. for periods ranging from 24 to 120 hours. At 24-hour intervals the tubes were read on a Klett-Summerson colorimeter fitted with a No. 42 filter. It was found necessary to filter immediately prior to reading to eliminate a flocculent precipitate that was formed on standing. The Klett values increased as both the concentration of l-ascorbic and holding time increased.

The ability of l-ascorbic acid to form dark compounds in cauliflower extracts was compared with the several other common organic acids—acetic, malic, citric, and oxalic, and to the sugars—fructose, lactose, galactose, sucrose, and glucose. The cauliflower extract was maintained at 1 millilitre and made

*Strachan, G. *Unpublished results.*

up to 10 millilitres with 0.1 M solutions of the acids or sugars. Figures 2 and 3 show that the l-ascorbic acid had a more pronounced effect on the Klett values than did the other compounds.

DISCUSSION

Paper chromatography has shown that aqueous cauliflower extracts contain many free compounds that could normally enter into non-enzymatic browning reactions. However, it cannot be shown that this reaction occurs under normal processing conditions without the addition of extra l-ascorbic acid. Ascorbic acid is known to discolour on prolonged heating or storage, but this reaction alone cannot account for the large increase of colour that occurs when this compound is added to cauliflower. Spectrophotometric and fluorometric properties of the reaction constituents tend to indicate similarity to the classic browning reaction (1). The reason for the formation of the coloured complex due to added ascorbic acid under the experimental conditions cannot be explained on the basis of existing evidence.

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ARTIFICIAL FREEZING OF 1-YEAR-OLD SHOOTS OF APPLE VARIETIES[1]

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ABSTRACT

One-year-old shoots of 35 apple varieties and 6 clonal rootstocks were subjected to artificial cold treatment in three winters at three dates – early winter, mid-winter, and late winter. The rate of temperature drop was 0.7°C. per hour and a minimum temperature of –37°C. was maintained for 8 hours. The freezing damage was determined by evaluating discoloration of tissues shortly after treatment, by estimating recovery of treated material following 3 weeks' forcing in the greenhouse, and by electrical conductivity measurements of water extracts from twig sections. Good agreement was obtained between the results of artificial freezing obtained in early or mid-winter and the known hardiness of varieties. Treatments in late winter, i.e. February or early March, did not produce reliable results. The recovery test gave consistent results if sufficient cold injury was produced, while the electrical conductivity measurements were most valuable in differentiating fine degrees of injury. The experience and the results obtained with known varieties seem to justify the suggestion that artificial freezing may successfully be used in screening unknown plant material for frost hardiness.

INTRODUCTION

In the tree fruit growing area of the interior of British Columbia, winters with damaging frost occur with sufficient frequency to make winter injury the main hazard in fruit production. On the other hand, winter injury does not occur with sufficient regularity to be used as a systematic measure of hardiness in variety testing and especially in fruit breeding. Artificial freezing, therefore, should be an essential phase of the routine work in the selection of tree fruit seedling material. The aim of the project, the first phase of which is reported here, is to adopt simple techniques of screening for frost hardiness of fruit tree seedlings before they are planted in seedling orchards. Several investigators have applied artificial freezing to tree fruit material and the results have, in general, agreed with its known or expected hardiness. However, further work with known material seemed to be justified in order to: 1) gain full confidence in the methods, before they are applied to material with unknown hardiness; 2) select simple procedures suitable for testing large amounts of material. In the present report, several procedures of evaluating frost damage are compared and the results of relative hardiness of certain apple varieties are given.

REVIEW OF LITERATURE

In freezing fruit tree material, detached 1-year-old shoots have been used in most instances. As exceptions to this, bark as a representative tissue was used by Siminovitch and Briggs (16), and Pisek (15); Thiele (18) froze germinating seeds; Olden (14) and Wilner (21) treated plants grown in containers; Loewel and Karnatz (11) artificially froze nursery trees *in situ* by means of a mobile freezing chamber; Nelson and Blair (13) subjected their test plants (rootstocks) to natural frost, but intensified its effect by sweeping the snow from the root area.

[1]Contribution No. 51 from the Research Station, Research Branch, Canada Department of Agriculture, Summerland, B.C.
[2]Pomologist–Breeding and fruit tree hardiness studies.

In respect to time of freezing treatment, Emmert and Howlett (5) and Anjou (1) obtained greater hardiness differences between varieties in fall or early winter than in late winter.

Most workers regulated the rate of temperature drop because they considered it influenced degree of injury although in some experiments this factor was ignored [Loewel and Karnatz (11), Thiele (18)]. In the experiments of Hildreth (10) and Siminovitch and Briggs (16), the rate of thawing showed an effect, but in most experiments it was not controlled.

The extent of injury on the detached treated material is usually measured by evaluating discoloration of tissues, by observing recovery of the material forced in the greenhouse (10, 2, 8), or by measuring electrical conductivity in plant tissue itself (4, 6, 7, 3) or in water extract from sections of tissues (4, 17, 5, 19, 20).

MATERIALS AND METHODS

In selecting the time and temperature conditions of the freezing treatment it was considered important to simulate as closely as possible the natural conditions of those winters when considerable frost damage occurred to apple trees in British Columbia. Apple trees had been severely damaged in the early winter freezes, in October and November, respectively, of 1935-36 and 1955-56, and in mid-winter of 1949-50. The damage in the early freezes was believed to be caused mainly by the fast drop in temperatures. The temperature records for the winter 1955-56 showed that the temperature drop did not exceed 0.9°C. per hour, as calculated for 3-hour periods.

After certain preliminary tests on methods of collecting material and evaluating injury, the following general procedure was adopted and used in the main experiments.

One-year-old twigs of 41 apple varieties, including certain clonal rootstocks, were subjected to cold treatment in three periods – early winter, mid-winter, and late winter – of 1956-57, 1957-58, and 1958-59. No appreciable injury due to natural frosts occurred in these winters before artificial freezing. The calendar dates of freezing varied slightly in different winters; the early winter samples were treated in late November or early December, mid-winter in late December or early January, and late winter in February or early March. The same number of varieties was not available for the freezing test each year. The effects of low temperatures were evaluated using three methods: estimates of discoloration of affected tissues, observations of recovery of the treated twigs after 3 weeks' forcing in greenhouse, and measurements of electrical conductivity of exosmosed substances from twig sections.

Twigs from bearing apple trees were collected at the Research Station, mainly from two variety orchards. Cultural treatments in both orchards were similar, but were not under strict control. Care was taken to collect shoots of medium size from the peripheral portion of the tree. Eighteen twigs were collected for each freezing, six shoots for each of three methods of evaluation.

The freezing was done in a 15-cubic foot home freezer, adapted with controls which permitted the temperature to be lowered at a pre-set rate per hour. In most experiments reported here, a temperature drop of 0.7°C. per hour and a minimum temperature of −37° ± 0.5°C. were used. The minimum temperature was maintained for 8 or 16 hours. The different periods of exposure were used as a means of regulating the extent of frost damage to twigs, as the temperature of −37°C. was the capacity of the freezer. The twigs in the freezing cabinet were placed on wire racks and a small fan was operated in the freezer to maintain uniform temperature. The rise of temperature after freezing was not controlled; it increased to −5°C. after 24 hours. The twigs were removed from the freezer when the temperature was about 0°C.

The material for discoloration tests was kept in polyethylene bags in a room at 21°C. and examined after 3 days. Discoloration in bark, cambium, wood and pith tissues and in leaf buds was rated, using values from 1 (very severe discoloration) to 10 (no apparent discoloration).

The twigs for forcing were kept with the cut ends in water in a greenhouse and examined after 3 weeks. Discoloration was evaluated as in the first lot of samples and observations were made on development of cambial tissues and on growth of leaf buds. The condition of twigs was rated from 1 (no recovery) to 10 (no evidence of injury).

For the electrical conductivity test, the portions of twigs from 5.5 millimetres in diameter upwards were cut in sections about 1 centimetre long, weighed and placed in Erlenmeyer flasks. Distilled water was added in the amount of five times the weight of the twig sections. The flasks were kept at 10° ± 2°C. for a period of 24 hours, for exosmosis to take place. Lower than room temperature was used in order to restrict fermentation in the liquid. The electrical conductivity of the exosmosites was measured with a wheatstone bridge. In some experiments, after the amount of electrolytes released in water due to frost injury was measured, twigs were boiled for 2 minutes in order to determine the total amount of electrolytes. The readings were again made after 24 hours of exosmosis and the ratio of the conductivity of frozen material to the conductivity of boiled material was calculated. In some other experiments, the conductivity readings were obtained also from unfrozen material and the differences were calculated between conductivity of frozen and that of unfrozen material.

EXPERIMENTAL RESULTS

The results from experiments dealing with methods will be discussed separately from those on the relative hardiness of varieties tested.

Sampling Techniques and Rates of Temperature Drop

An experiment was conducted in early winter of 1956-57, using five apple varieties, ranging from very hardy to very tender, as follows: Antonovka, McIntosh, Spartan, Delicious, and Newtown. One-year-old terminal shoots were frozen at −37°C., using two rates of temperature drop, 0.7°C. per hour and 1.0°C. per hour. For the electrical conductivity test, two methods of taking samples were compared: a 20-centimetre section

TABLE 1.—AVERAGE VALUES OF SPECIFIC CONDUCTIVITY, IN MICROMHOS, OF EXOSMOSIS LIQUID OF TISSUE FROM FROZEN (F) AT −37°C. AND UNFROZEN (U) TWIGS AND THEIR DIFFERENCE (F-U)

Varieties	Temp. drop 0.7°C./hour			Temp. drop 1.0°C./hour			Average F-U[1]
	F[1]	U	F-U[1]	F[1]	U	F-U[1]	
Antonovka	187	122	65	242	111	131	98
McIntosh	252	133	119	325	120	205	172
Spartan	294	151	143	373	141	232	188
Delicious	311	144	167	409	143	266	217
Newton	359	157	202	436	160	276	239
LSD (0.05) Sampling methods			41.9			42.2	28.5
A	264	137	127	331	130	201	164
B	287	143	144	365	135	230	187
C	291	145	146	374	140	235	190
LSD (0.05)			N.S.			N.S.	22.1

[1]Higher numerical values indicate greater damage

of the twig from 5.5 millimetres in diameter upwards (A) and the whole twig (B or C) was used for exosmosis. The whole twigs were divided into two size groups: large (B) and small twigs (C), approximately 45 and 30 centimetres long, respectively. Conductivity tests were also made for unfrozen material (U) similar to those for frozen twigs (F). Two tests were made with each of the two rates of temperature drop. The average data for conductivity values are given in Table 1. Analysis of variance was made for the F-U data.

Highly significant differences, ($P < 0.01$), were found between rates of temperature drop, varieties, and significant differences ($P < 0.05$) between sampling methods A *vs.* B or C. The conductivity values F-U for the lots frozen at the faster rate of temperature drop (1.0°C./hr.) were 40 per cent to 100 per cent higher than those for the lots frozen at the slower rate (0.7°C./hr.). It appears that the rate of temperature drop, even in the narrow range tested, is a factor likely to affect the results. The whole twig samples differentiated better between varieties than the 20-centimetre sections of the twigs. The results were not affected by the twig size if it was kept within the limits indicated above, i.e. 30 to 45 centimetres long. Later experiments, however, showed that, by using very large shoots, conductivity readings were unduly increased.

Very close association was found to exist between the conductivity values of frozen material (F) and those of the difference between frozen and unfrozen twigs (F-U); the correlation coefficient r was calculated to be + 0.977. It would appear safe to use conductivity values of the frozen material only.

TABLE 2.—COEFFICIENTS OF VARIABILITY (BETWEEN VARIETIES WITHIN A TEST) OF SPECIFIC CONDUCTIVITY VALUES IN MICROMHOS OF EXOSMOSITES FROM 20-CENTIMETRE SECTIONS AND TIPS OF SHOOTS OF 41 VARIETIES FROZEN AT −37°C. IN JANUARY AND FEBRUARY, 1957

20-centimetre section		Tips above the 20-centimetre section	
January samples	February samples	January samples	February samples
43.36	21.14	76.14	29.86

The variety freezing test, which was begun with over 40 varieties and clonal rootstocks and conducted over a 3-year period, was modified in 1956-57 in order to give a comparison between two sampling methods, i.e., the 20-centimetre sections of twigs and the tips of twigs above the 20-centimetre section. The sampling method giving a greater spread between varieties should be preferred to the one with a narrow range in the conductivity values. As a measure of variation between varieties within a test, the coefficients of variability were calculated and are given in Table 2.

The data refer to 41 varieties representing a wide range of hardiness. The tip samples gave higher values than the corresponding samples of 20-centimetre sections. In the February samples, the spread between varieties was relatively low and the readings for certain varieties did not fully correspond to their known relative hardiness. Again, as in the 5-variety comparison, the relationship between the F and F-U values was tested. A correlation coefficient of +0.937 was found between the January readings for shoot tips.

The two experiments described above indicated that the whole twig, which includes the tip, rather than a section of the middle portion of the twig, should be used as a sample.

Electrical Conductivity Expressed in Absolute vs. Relative Values

A comparison was made of readings of electrical conductivity in exosmosed liquid from frozen samples expressed: 1) in micromhos, and 2) in percentage of "total electrolytes". The latter were determined in the exosmosites of boiled twig sections. For comparison, 25 varieties treated in January, November, and December, 1958, were available. The results are given in Table 3 and they represent freezing conducted in two seasons: 1957-58 (January samples), and 1958-59 (November and December samples).

Analysis of variance of the data showed similar F values for variation due to varietal differences in both comparisons, viz., $F = 8.26^{**}$ for conductivity in micromhos and $F = 8.20^{**}$ for conductivity in percentage of total electrolytes. However, the F value for variation due to dates of treatment was highly significant ($F = 11.82^{**}$) for conductivity in micromhos, but was negligible ($F = 0.24$) for the conductivity expressed as percentage of total electrolytes. The seasonal differences in total electrolytes

TABLE 3.—A COMPARISON OF ELECTRICAL CONDUCTIVITY VALUES EXPRESSED IN MICROMHOS AND IN PERCENTAGES OF TOTAL ELECTROLYTES. TWIGS FROZEN AT −37°C., TEMPERATURE LOWERED AT 0.7°C. PER HOUR. 1957-58 (JANUARY SAMPLES) AND 1958-59 (NOVEMBER AND DECEMBER SAMPLES)

Variety	Conductivity in micromhos				Conductivity in per cent of total electrolytes			
	Jan.	Nov.	Dec.	Total	Jan.	Nov.	Dec.	Total
Columbia	267	149	213	629	27.3	17.2	23.1	67.6
Dr. Bill	262	211	211	684	24.6	23.5	24.7	72.8
Melba	280	260	245	785	29.8	26.9	28.6	85.3
Minjon	358	313	250	921	31.0	33.7	27.8	92.5
Crimson Beauty	384	268	264	916	34.5	30.1	29.4	94.0
Lodi	330	352	279	961	29.8	34.8	30.7	95.3
0-271	328	311	283	922	29.2	34.5	31.8	95.5
McIntosh 3	290	325	310	925	28.5	35.4	34.3	98.2
0-292	353	351	345	1049	31.9	32.1	34.8	98.8
McIntosh 9A	302	313	331	946	31.0	33.3	35.4	99.7
M.M. 104	272	303	316	891	31.8	34.7	33.5	100.0
Metzger	448	321	315	1084	39.0	32.6	33.5	105.1
Delicious 3	364	330	323	1017	34.2	34.3	37.0	105.5
Spartan	355	335	302	992	32.6	40.1	36.4	109.5
M. II	344	359	319	1022	36.6	37.0	36.5	110.1
Jubilee	398	387	406	1191	37.4	36.2	37.4	111.0
Minnetonka Beauty	365	333	458	1156	31.9	32.0	47.2	111.1
Melrose	444	402	349	1195	38.5	39.9	36.0	114.4
S-4-8	471	427	364	1262	41.8	41.0	39.1	121.9
Golden Delicious	412	394	389	1195	38.5	39.8	43.9	122.2
Delicious 9D	444	384	339	1167	44.6	42.7	38.8	126.1
Rome Beauty	459	451	373	1283	38.8	47.5	40.1	126.4
Jonathan	569	381	445	1395	45.7	38.9	43.6	128.2
Monroe	574	497	410	1481	44.7	43.8	43.4	131.9
Winesap	553	344	427	1324	48.5	36.4	47.5	132.4
Total	9626	8501	8266	26393	882.2	878.4	894.5	2655.1

may mask the varietal differences in conductivity due to freezing. In using the ratio of electrolytes released due to freezing to the total electrolytes, the seasonal differences are greatly reduced. Column totals in the table also illustrate the seasonal effects on the two groups of readings. Emmert and Howlett (5) and Wilner (20) used per cent of total diffusion of electrolytes due to low temperature injury as a measure for hardiness.

Time of Cold Treatment

Samples collected and frozen in early winter and in mid-winter gave comparable results in all three seasons but those collected and frozen in late winter (February or early March) did not produce reliable values. First, the late winter samples gave a much narrower range of frost resistance between varieties than the samples collected in early or mid-winter. Second, certain varieties which are considered hardy in British Columbia and elsewhere and were hardy in the early and mid-winter tests had lost their relative hardiness in late winter. As apple trees in the Okanagan are

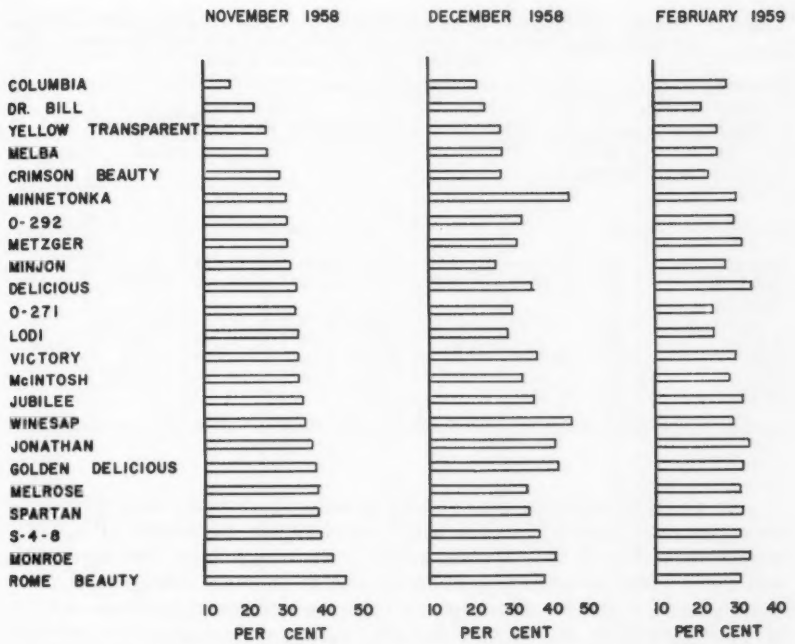

FIGURE 1. Electrolytes released from twig sections due to freezing injury in percentage of total electrolytes. Treatments at different periods of the winter of 1958-59.

injured by natural frost mostly in early and mid-winter, the late winter freezing tests may be considered to be of lesser importance. In comparing the methods of freezing evaluation and the relative varietal hardiness, February tests were, therefore, omitted.

The range of varietal hardiness and the changes of relative hardiness of varieties in three tests in the winter of 1958-59 are illustrated in Figure 1. The bar graphs indicate the electrolytes released due to freezing injury in percentage of total electrolytes.

Methods of Evaluating Cold Injury

Although a total of 41 varieties and clonal rootstocks were subjected to cold treatment during the 3-year period, the plant material was not available from all varieties each year and for every treatment. The performance of 23 varieties was followed through all three seasons and all tests, and full analysis was made on the data. Separate analyses of variance were made for each of the three methods of evaluating freezing injury. The variation was separated as being due to: varieties (23); years (3); dates of treatment (2 early and mid-winter); and their two-way and three-way interactions. The three-way interactions were used as the error terms. A summary of the analyses is given in Table 4.

TABLE 4.—THE M.S. AND F VALUES OF ANALYSES OF VARIANCE OF DATA FOR THREE METHODS OF EVALUATING FREEZING INJURY IN 23 APPLE VARIETIES TREATED OVER 3-YEAR PERIOD AT TWO DIFFERENT DATES

Source of variation	Degree of freedom	Recovery ratings		Discoloration ratings		Electrical conductivity micromhos		F required at 1 per cent
		M.S.	F.	M.S.	F.	M.S.	F	
Varieties (V)	22	21.09	32.60**	12.88	28.00**	33,736	26.67**	2.28
Years (Y)	2	9.95	15.31**	28.98	63.00**	134,866	106.61**	5.12
Dates of freezing (D)	1	26.69	45.68**	11.02	23.96**	82,951	65.57**	7.24
VY	44	1.31	2.02*	1.49	3.24**	5,319	4.20**	2.03
VD	22	0.57	0.88	0.67	1.46	2,209	1.75	2.28
YD	2	6.11	9.40**	3.81	8.28**	20,226	15.99**	5.12
VYD	44	0.65		0.46		1,265		

In all three analyses, the primary sources of variation and their two-way interactions gave F values which were highly significant ($P < 0.01$), except those for all variety-date interactions, which were non-significant, and the F value for variety-year interaction in recovery ratings which was significant ($P < 0.05$). The largest F value for differences between varieties was obtained from the data of recovery ratings. At the same time these ratings were affected by yearly and seasonal differences to a lesser degree than the readings of electrical conductivity. The latter values gave the lowest magnitude in F values for differences between varieties and the highest fluctuation due to yearly and seasonal effects and their interactions. It would appear that the recovery ratings, although being subject to personal judgement, should be used in evaluating freezing injury. Discoloration ratings ran very closely to recovery ratings and therefore could be omitted. Conductivity readings, which may trace small differences in the amount of injury, not detectable by the first two methods, should be used as a valuable supplement to the recovery ratings.

The relationship between the three methods of evaluating injury was expressed also as the *r* values of linear correlation. The *r* values were found to be:

between recovery ratings and discoloration ratings	+0.840
between recovery ratings and conductivity readings	−0.712
between discoloration ratings and conductivity readings	−0.697.

Relative Frost Hardiness of Varieties

Average ratings of frost hardiness are given in Table 5 for those varieties that were subjected to cold treatment for at least two seasons. The varieties are arranged in the table in decreasing order of frost hardiness as determined by recovery ratings. In the last column, varieties are assigned to hardiness groups.

TABLE 5.—AVERAGE RATINGS OF FROST HARDINESS OF 35 VARIETIES, EVALUATED IN EARLY AND MID-WINTER OF THE SEASONS 1956-57, 1957-58, AND 1958-59

Variety	Recovery rating (1-10)[1]	Discoloration rating (1-10)[1]	Conductivity in micromhos	Conductivity in per cent of total electrolytes	Hardiness group (1-5)[2]
Antonovka	9.0	8.7	216	24.7	1
Red van Buren	9.0	9.5	269	26.6	1
Columbia	8.8	8.8	238	22.5	1
Dr. Bill	8.8	8.8	261	24.3	1
Hibernal	8.5	8.5	240	22.7	1-2
Beautiful Arcade	8.5	8.5	222	27.4	1-2
Yellow Transparent	8.5	8.4	312	27.8	1-2
Melba	8.0	8.2	278	28.6	1-2
Empire Red	8.0	7.8	356	29.8	1-3
Crimson Beauty	8.0	8.8	302	31.3	1-2
Wealthy	7.8	8.8	354	30.4	1-3
0-292	7.8	8.0	353	32.9	2-3
0-277	7.8	8.3	409	41.2	2-4
Lodi	7.5	7.3	325	31.8	2
0-271	7.5	8.0	341	31.8	2
Minjon	7.3	7.2	346	30.8	2
McIntosh 9A	6.7	7.0	341	33.2	2-3
Victory	6.5	6.5	338	36.5	2-3
Metzger	6.3	6.8	408	35.0	2-4
O-276	6.3	7.0	553	41.5	2-5
McIntosh 3	5.8	6.6	353	32.7	2-3
Minnetonka Beauty	5.8	5.8	428	37.0	3-4
Spartan	5.5	6.5	349	36.4	2-3
Kendall	5.3	7.3	505	42.9	2-5
Jonathan	4.8	5.8	466	42.7	3-5
Stayman	4.5	5.3	371	39.2	3-4
Melrose	4.3	6.2	422	38.1	3-4
S-4-8	4.3	5.2	473	40.6	3-5
Delicious 10B	4.3	6.0	350	41.5	2-4
Winesap	4.2	5.2	413	44.1	3-4
Jubilee	4.0	5.5	475	37.0	3-5
Turley	4.0	5.8	459	42.9	3-5
Delicious 3	3.8	5.7	389	35.2	3-4
Rome Beauty	3.8	4.5	436	42.1	4
Monroe	3.8	4.7	520	44.0	4-5
Delicious 9D	3.3	4.8	383	42.0	3-4
Golden Delicious	3.2	4.2	456	40.7	4-5
Newtown	2.0	3.5	479	47.9	5

[1]Ratings from 1 — *complete killing*, to 10 — *no apparent injury*
[2]Grouping from 1 — *very hardy*, to 5 — *tender*

In order to classify the varieties in relative hardiness groups by taking into account the figures of all four columns of hardiness ratings, arbitrary hardiness groups were set up, taking the recovery ratings as the basis for grouping. The recovery ratings from 1 to 10 were divided into five equal groups, and the values of the other three columns were divided into the five groups roughly corresponding to the groups of recovery ratings, as shown in Table 6.

The order of varieties in Table 5 and classification of varieties in hardiness groups corresponded very well to the known varietal hardiness.

TABLE 6.—RANGE OF VALUES OF FROST HARDINESS EVALUATIONS FOR FIVE ARBITRARY HARDINESS GROUPS. GROUP 1—MOST HARDY; GROUP 5—LEAST HARDY

Hardiness group	Range of values for hardiness groups			
	Recovery rating	Discoloration rating	Conductivity in micromhos	Conductivity per cent of total electrolytes
1	8.1 — 10.0	8.6 — 10.0	< 300	< 30.0
2	6.1 — 8.0	7.1 — 8.5	301 — 350	30.1 — 35.0
3	4.1 — 6.0	5.6 — 7.0	351 — 400	35.1 — 40.0
4	2.1 — 4.0	3.6 — 5.5	401 — 450	40.1 — 45.0
5	0.0 — 2.0	0.0 — 3.5	> 450	> 45.0

There were only a few exceptions. Samples of the same varieties (McIntosh or Delicious) from different orchards behaved similarly.

Certain varieties showed a wide range in their hardiness grouping, when all four evaluations were taken into account. These varieties include: Empire Red, Wealthy, 0-277, Metzger, 0-276, Kendall, Jonathan, S-4-8, Delicious 10B, Jubilee, and Turley. In all the above varieties, there were difficulties in securing uniform twig samples, and in most instances the shoots for freezing came from relatively young trees and were more vigorous than the average for all varieties.

Under the conditions of the experiment, hardy varieties (first 10 in Table 5) were rated 8 or higher in recovery, and in the exosmosis test they lost due to freezing up to 30 per cent of their total electrolytes. On the other end of the table, tender varieties (last 14 in Table 5) were rated 5 or lower in recovery and most of them lost over 40 per cent of their electrolytes due to freezing. The conductivity values of plants of different hardiness groups correspond very well with those established by Wilner* working with three apple varieties.

DISCUSSION

The results presented above assisted in establishing full confidence in artificial freezing tests as a means of selecting unknown plant material for frost hardiness. The data on 35 apple varieties, mostly of known frost hardiness, corresponded closely to expectations (Table 5). Where discrepancies between the obtained and the expected results occurred, they almost invariably could be traced back to insufficient uniformity of plant material available for freezing. The importance of selecting uniform plant material, that is comparable between varieties and years, can never be overemphasized. For critical tests, material for freezing should be grown in special plantings at close distances (in order to ensure greater uniformity of soil), all plants should be of the same age, on the same rootstock, treated uniformly during the growing season, and well hardened before freezing tests are made.

*Wilner, J. *Personal communication.*

In individual freezing tests unexpected results occurred. In most of these instances, varieties showed greater injury than was expected. In some varieties it occurred more frequently than in others. Wealthy, Minjon, Minnetonka Beauty, Kendall, Jonathan, and Winesap showed greater inconsistency than most other varieties. Havis and Lewis (9) in Ohio found that Stayman, Grimes Golden, and Jonathan were inconsistent in hardiness, and stated that varietal inconsistency in frost injury is general. Inconsistency in varietal frost hardiness is not confined to the artificially frozen material. Great variation in the relative hardiness of varieties was noted in a large-scale survey in commercial orchards after the severe winter of 1949-50 [Mann *et al.* (12)]. Many factors contribute to frost hardiness, or to lack of it, and certain combinations of factors may affect one variety more than another and cause differences in varietal responses. Artificial freezing tests may be considered reliable, if the results can be repeated on the same plant material the same year. Table 4 shows non-significant F values for the variety and date of freezing interaction, indicating that within 1 year varietal responses are reproducible in artificial freezing tests. Significant or highly significant variety-year interactions may have resulted from changes in physiological conditions of trees, caused by the crop of the previous year, pruning, etc. In some tests inadequate differentiation between varieties of moderate hardiness was obtained because the injury was insufficient. Brierley and McCartney (2) also found that freezing injury must be rather severe in order to bring out varietal differences.

Certain difficulties were encountered in estimating freezing damage. In estimating recovery it was noted that intensity of discoloration of the bark, wood, and pith tissues depends not only on the extent of frost injury, but also on normal varietal characteristics. Thus certain varieties, such as Delicious, Winesap, Newton and most of the clonal rootstocks, did not discolour as much as was expected from the known relative tenderness of the varieties and from other methods of evaluation. On the other hand, twigs of varieties such as Minnetonka Beauty, McIntosh, Jubilee, S-4-8, Rome Beauty, and Golden Delicious discoloured more intensively than could be expected from the amount of injury that subsequently developed. Also, growth and development of leaf buds may be affected not only by frost injury, but also by the depth of dormancy and the rate of development in spring which is a varietal characteristic. The conductivity values seemed to depend to a certain extent on the bark-wood-pith ratio in the twig. Varieties with a large proportion of bark and pith in the twigs, such as Minnetonka Beauty, McIntosh, S-4-8, Rome Beauty, and 0-276, usually showed relatively high conductivity values and were rated more frost tender by conductivity than by the other methods. Moreover, conductivity readings are determined to a great extent by the condition of wood and pith – the tissues which are of secondary importance in recovery. On the other hand, in recording the recovery, the condition of the critical tissues, such as cambium and bark, can easily be assessed. The above two methods, recovery test and conductivity reading, supplement one another and both should be used. Conductivity readings should be expressed as percentages of total electrolytes.

If we take a hypothetical case and wish to discard tender varieties of Table 5, using as arbitrary limits the recovery ratings of 5 or lower and conductivity readings of 40 per cent and higher, then Jonathan, S-4-8, Delicious 10B, Winesap, Turley, Rome Beauty, Monroe, Delicious 9D, Golden Delicious, and Newtown would be eliminated. All the above varieties are considered to be tender in the Okanagan Valley; the theoretical screening did not discard any hardy variety. Four varieties — Stayman, Melrose, Jubilee and Delicious from Orchard 3 — would be under question as their conductivity values are below 40 per cent, but their recovery ratings under 5. Similar situations might be expected to arise when unknown seedling selections had to be discarded based on artificial freezing.

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ACCELERATION OF SEED MATURITY IN SLOW-BOLTING LETTUCE BY VERNALIZATION

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ABSTRACT

Seed maturity of the slow-bolting lettuce variety Imperial 456 was greatly accelerated by placing newly-seeded flats in cold chambers at 33, 36 or 39°F. for periods of 4 weeks or longer, before growing the seedlings in the greenhouse and transplanting to the field. The practice of holding flats at 65°F. for 24 hours or more immediately after sowing failed to accelerate maturity. This treatment caused quicker emergence and greater etiolation during vernalization at the higher temperatures, making subsequent pricking-out difficult and slow. The most effective and practical method was to place the newly-seeded flats immediately in cold chambers at 36°F. for 4 weeks, or 33°F. for 6 weeks.

INTRODUCTION

Widespread public acceptance of hard-heading varieties of lettuce has made seed production important. In British Columbia there has been little difficulty in producing seed of varieties which bolt readily, but attempts to produce seed of the hard-heading types, such as Great Lakes and Imperial 456, have met with little success.

Several workers have attempted to accelerate seed maturity of lettuce. Knott *et al.* (3) found that loose heads and rapid seed development resulted when seed was pre-germinated for 1 day at 70°F. and then held at 40°F. for 5 or more days. Flowering was earlier and seed stalks developed 2 or 3 weeks earlier when moistened seeds were kept at 4°C. for 28 days before planting (2). Thompson and Kosar (7), however, found no significant advantage from a 28-day chilling period at 1 to 2°C.; but there was a trend towards an increase in stem length from the vernalizing treatment. Seed maturity of three slow-bolting varieties was accelerated when seedlings were vernalized either in moist soil or Petri dishes (1). In Utah and Idaho, Pollard and Hawthorn (4) grew seed of crisp-heading varieties, such as Great Lakes, from fall sowings; the seedlings were subject to a natural vernalization process and seed was harvested several weeks ahead of the spring-planted crop.

Pre-germination at 60 to 70°F. prior to vernalization has been the usual procedure (3, 6), although only in seedlings pre-germinated less than 3 days at 60°F. prior to the cold exposure was flowering promoted (5).

This paper presents the results of experiments conducted during the period 1952 to 1958 to determine whether the time to seed maturity of hard-heading varieties could be shortened by vernalization under British Columbia coastal conditions.

MATERIALS AND METHODS

In all experiments the seed was sown broadcast in a sterilized 1:1 soil-sand mixture in standard 12- by 24- by 4-inch wooden flats and lightly covered with the same mixture. Walk-in cold chambers controlled to

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within ±1°F. were used for all vernalization treatments. In 1952, one series of flats was held in the greenhouse for 2 days and another for 4 days at 63°F. before vernalization at 39°F. for 1, 2, and 4 weeks. In 1953, a period of 4 weeks only was employed, but the pre-chilling period was shortened to 24 hours. In addition to 39°F., vernalization treatments at temperatures of 36 and 33°F. were included to determine whether emergence would be retarded at the same time that developmental processes were accelerated. In 1956, 1957 and 1958, treatments were included in which an initial period at 65°F. was omitted and, immediately after sowing, the flats were placed in chambers at the vernalizing temperatures. Treatments with 36 and 39°F. temperatures for periods of 2 and 4 weeks were included in 1956, 36°F. only in 1957 with periods up to 6 weeks, and temperatures of 33 and 36°F. in 1958 for periods of 6, 8 and 10 weeks. In each experiment sowings were so arranged that all treatments were completed at the same time. Then the flats were removed from the cold chambers and held in subdued light at 55 to 60°F. for a day before being put in the greenhouse. Seedlings were pricked out 60 per flat, when the first true leaf had developed, grown to transplanting size in the greenhouse, and hardened off in cold frames before planting in the field. The unvernalized check treatments were sown and grown at normal greenhouse temperatures. In 1952, check plants were transplanted to the field 16 days before the vernalization treatments. In all other experiments, checks were sown so as to produce plants ready for transplanting at the same time as those of the vernalization treatments. Time of transplanting varied from April 21 in 1956 to May 12 in 1958.

Except in 1952 and 1953, when treatments were in duplicate only, the plot design was a 6-replicate randomized block. Plant spacings in all experiments were 1 foot in rows 3 feet apart. In the preliminary trial in 1952, four varieties – New York 515, Great Lakes, Pennlake and Imperial 456 – were included, while Imperial 456* was used in all other experiments.

To expose the growing point and thus facilitate normal seedstalk development, the heads were removed by twisting and pulling after a sharp blow with the palm of the hand. The outer leaves were also removed to reduce rot. *Botrytis* sp. infected the plantings at or shortly after the time of heading and plant losses occurred in several years, despite a program of spraying with Bordeaux mixture. Losses were most serious in 1957 when plant stands at maturity were so uneven that maturity data were not analysed.

Observations on maturity were made each September when decreasing temperatures and the imminence of fall rains gave little likelihood of further ripening of seed. Maturity data for 1952, 1953 and 1956 were based on plants with one or more mature heads of flowers as indicated by expansion of the pappus. In 1957 and 1958, plants were rated as mature when 10

*Stokes Seeds Ltd., St. Catharines, Ont.

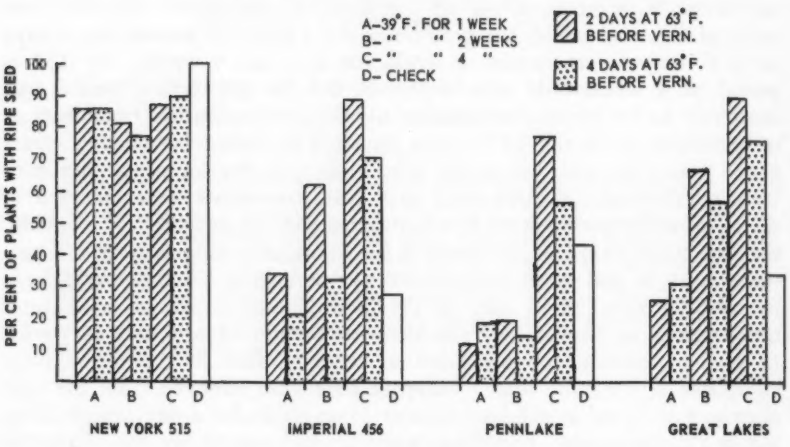

FIGURE 1. Seed maturity of four varieties of lettuce at September 25, 1952, as affected by different seedling vernalization treatments.

per cent or more of the flower heads were ripe. An analysis of co-variance was made on the 1956 and 1958 data because of differences in the plant numbers, but in neither year did the variation in plant stand influence treatment effects.

In 1954 and 1955, identical experiments were conducted to include five vernalization treatments: 39°F. for 2 and 4 weeks, and 36°F. for 2, 4 and 6 weeks, with an initial 24-hour period at 65°F. in all cases. Unusually cool, dull weather in both years so delayed maturity that, although some advantage was obtained from vernalization, especially at 4 weeks or more of seedling chilling, the data are not presented.

RESULTS

Preliminary Experiments, 1952 and 1953

In 1952, seedlings in the series of flats held in the greenhouse at 63°F. for 4 days immediately after sowing were emerged and their cotyledons expanded and fully pigmented before being placed in the cold chamber. These seedlings remained green during the treatment at 39°F. and did not become etiolated. Seedlings in the 2-day series, on the other hand, emerged in the cold chamber. Their cotyledons did not expand, and etiolation in the 4-week treatment led to subsequent difficulty in pricking out. The 4-week cold treatment caused more rapid seed maturity for the varieties Imperial 456, Pennlake, and Great Lakes, than the cold treatment for the shorter periods (Figure 1). On the other hand, with the easy-bolting New York 515, there were no differences in vernalization treatments. There appeared to be a fairly consistent advantage also from the 2- over the 4-day pre-chilling treatment in hastening seed maturity.

TABLE 1.—THE EFFECT OF DIFFERENT VERNALIZING TEMPERATURES ON SEEDLING HEIGHT AND MATURITY OF IMPERIAL 456 LETTUCE TRANSPLANTED MAY 7, 1953

Vernalizing treatment	Total plants	Seedling stage or height after vernalization	Plants with mature seed September 28
		inches	per cent of total
39°F. for 4 weeks	50	0.5	98
36°F. for 4 weeks	58	Emerging	95
33°F. for 4 weeks	50	Emerging	82
Check	22		7

TABLE 2.—THE EFFECT OF VERNALIZATION TREATMENTS UPON SEEDLING HEIGHT AND SEED MATURITY OF IMPERIAL 456 LETTUCE TRANSPLANTED APRIL 21, 1956

Vernalizing treatment	Seedling stage at end of treatment	Plants with mature seed September 21
		per cent
36°F. for 4 weeks	First sign of emergence	54
36°F. for 4 weeks after 24 hours at 65°F.	Emerging	38
36°F. for 2 weeks after 24 hours at 65°F.	No emergence	19
39°F. for 2 weeks after 24 hours at 65°F.	0.1 inch high	17
Check		0
Sig. diff. (P. = .01)		12

In 1953, with the pre-chilling period shortened to 24 hours at 65°F., lettuce seedlings emerged at all three temperatures, but at 33 and 36°F. growth was more retarded during the vernalization period, and the seedlings were easier to handle at time of pricking out than those from the 39°F. vernalization treatment. The check plots had a poorer stand because of *Botrytis* rot. In most of the experiments, this disease was more severe in the slower-bolting, untreated plants. Although there was a tendency in this experiment for earlier maturity at the 36 and 39°F. vernalization temperatures, all three greatly hastened seed maturity.

1956 Experiment

This experiment included a treatment to determine whether chilling the seedlings would be effective in hastening maturity when the initial period at 65°F. was omitted, and also whether its omission would result in a lessening of seedling etiolation during the vernalizing treatment. The 1953 treatment of 39°F. for 4 weeks was repeated with the initial 65°F. period omitted, but at the end of this time seedlings were even taller than in 1953 and their further rapid elongation upon removal of the flats from the cold chamber made pricking out impractical. With a vernalizing temperature of 36°F., however, germination was much slower and, at the end of 4 weeks, seedlings were just emerging. There was no difference in

TABLE 3.—THE EFFECT OF VERNALIZING TREATMENTS UPON SEEDLING HEIGHT AND SEED MATURITY OF IMPERIAL 456 LETTUCE TRANSPLANTED MAY 2, 1957

Vernalizing treatment	Seedling stage at end of treatment	Total no. of plants at maturity	Plants with mature seed September 21
			per cent
36°F. for 6 weeks	Emerging	113	94
36°F. for 5 weeks	First sign of emergence	119	83
36°F. for 5 weeks after 24 hours at 65°F.	0.2 inch high	115	82
36°F. for 4 weeks	No emergence	138	80
36°F. for 4 weeks after 24 hours at 65°F.	First sign of emergence	94	72
Check		48	10

TABLE 4.—THE EFFECT OF VERNALIZING TREATMENTS UPON SEEDLING HEIGHT AND SEED MATURITY OF IMPERIAL 456 LETTUCE TRANSPLANTED MAY 12, 1958

Vernalizing treatment	Seedling height at end of treatment	Plants with mature seed September 5
	inches	per cent
33°F. for 6 weeks after 24 hours at 65°F.	Emerging	68
33°F. for 6 weeks	Emerging	74
33°F. for 8 weeks	0.2	69
33°F. for 10 weeks	0.5	69
36°F. for 6 weeks after 24 hours at 65°F.	1.0	68
36°F. for 6 weeks	0.6	76
36°F. for 8 weeks	1.2	71
36°F. for 10 weeks	1.5	76
Check		10
Sig. diff. (P. = .01)		13

the stage of development at this time, whether or not the flats had first been held for 24 hours at 65°F. Maturity data (Table 2) show that the 4-week cold treatment was much more effective than 2 weeks. In the 4-week treatment there was also a more pronounced effect upon the hastening of seed production when the initial period at 65°F. for 24 hours was omitted.

1957 Experiment

In this experiment the merit of the initial period at 65°F. for 24 hours was again tested and vernalizing periods of 4, 5 and 6 weeks included. High incidence of *Botrytis* head rot caused severe plant losses and therefore maturity data could not be analysed. There was no evidence from the remaining plants, however, that the inclusion of the initial 65°F. period had hastened seed maturity (Table 3). There was an indication, on the other hand, that the 6-week vernalizing period was more effective than the shorter periods in hastening seed maturity.

1958 Experiment

This experiment investigated longer vernalization periods at temperatures of 33° and 36°F., and data on seedling height at the end of the treatments show that seedling growth was much slower at 33° than at 36°F. (Table 4). There was no significant difference in seed maturity, however, between vernalization at these temperatures nor between the different vernalization periods. The practice of holding the flats after sowing at 65°F. for 24 hours before placing them in the cold chamber again failed to accelerate seed maturity.

DISCUSSION

Although seedling etiolation during vernalization has not been referred to by other workers, it became evident during this study that it is an important consideration if vernalization is to have a practical application in seed production of slow-bolting lettuce. While in these experiments the vernalized lettuce seedlings were pricked out and grown on to transplanting size in the greenhouse, they can also be grown to the transplanting stage without pricking out, by using a richer soil mix and sowing thinly. In the former method, this study has shown that seedling etiolation makes pricking out a slow and laborious procedure while it quickly renders plants not pricked out unsuitable for transplanting.

Two main factors were found to bear on this problem. One of these is the initial treatment of 65°F. for 1 or 2 days which other workers (3, 6) used before vernalization. In these studies the practice led to more pronounced etiolation, and as there was also a fairly consistent trend towards a delay in seed maturity from its use, its inclusion did not appear to have any merit. In 1952, etiolation was avoided by an initial 4 days at 63°F. in the greenhouse; seedlings emerged and attained full green pigmentation, but the effectiveness of vernalization tended to be reduced by this treatment.

The other factor is the vernalizing temperature itself. At 39°F., there was fairly rapid seedling elongation following emergence about 2 weeks after the commencement of the chilling period. At the end of 4 weeks the seedlings were too tall for subsequent handling, even when the 1-day initial period, at 65°F., was omitted. Since a 2-week vernalization period was inadequate to materially affect the time of seed maturity, the 39°F. temperature appeared unlikely to be very reliable. Because of the slower rate of emergence and elongation, the 36° and 33°F. temperatures were more useful. At 36°F., without an initial period of 65°F., seedlings were usually at the point of emergence after 4 weeks, and at 33°F. after 6 weeks. When removed at this stage, seedlings were held in intermediate light and temperature for a day before being subjected to greenhouse conditions without resulting in the excessive elongation which rendered later handling impractical.

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THE EFFECT OF SWATHING AT DIFFERENT STAGES OF MATURITY ON THE BUSHEL WEIGHT AND YIELD OF OATS

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ABSTRACT

Swathing tests were conducted over a 4-year period to determine the earliest stage of maturity at which oats could be cut without loss of bushel weight or yield.

Cutting started when the kernel moisture content of the standing crop approximated 50 per cent and continued daily until the moisture content reached 14 per cent. The weight per measured bushel, 1000-kernel weight, and yield in bushels per acre were determined at the time the swath was picked up and threshed with the combine.

An analysis of variance of the data indicated that oats may be swathed at a stage of maturity defined by a kernel moisture content of 35 per cent without affecting bushel weight or yield. Kernel moisture at swathing was significantly, negatively correlated with the bushel weight, 1000-kernel weight, and yield for the full range of the test, but this relationship became of a lower order as maturity advanced and was not correlated at a moisture level below 35 per cent.

INTRODUCTION

Oats is usually one of the last crops seeded each spring in Western Canada and it is generally sown on stubble in a 3-year rotation. Maturity is reached approximately 14 days earlier than wheat. If allowed to develop to an advanced stage substantial losses from shattering by wind and rain, and in harvesting, can occur. The harvesting procedure is to swath oats in order to reduce losses and dry the green material, but there are differences of opinion as to when swathing should commence and how long a period of time is required for the cut grain to dry before threshing is possible.

This study, with Garry Oats, was conducted at the Experimental Farm, Swift Current, Saskatchewan, during the years 1957 to 1960, inclusive. It was undertaken to determine the earliest stage of maturity at which oats could be swathed without loss of yield or quality.

REVIEW OF LITERATURE

Loss of yield and a depression of quality of oats by early harvesting are reported by many investigators (7, 8, 10, 11, 12, 13), who define the stage of maturity at which losses became insignificant as the dough stage. Others (1, 2) qualify their statements by suggesting that early cutting may be justified under certain climatic conditions.

It has been recorded (9, 15, 16, 19) that an early harvest, up to 10 days before maturity, will not decrease yield or quality of oats but yield losses will increase due to natural causes if the grain is left for straight combining.

The movement of certain plant nutrients from the soil (3) ceases at a stage of development when the oat kernel begins to form but some compounds from the straw and chaff continue to move into the kernel until maturity is reached.

TABLE 1. — EFFECT OF KERNEL MOISTURE CONTENT AT DIFFERENT DATES OF SWATHING ON WEIGHT PER MEASURED BUSHEL, WEIGHT PER 1000 KERNELS AND ON YIELD, 1957-1960

Swathing Tests With Garry Oats
Swift Current, Saskatchewan

1957					1958					1959					1960				
Swathing date	K.M.C. at swathing	W.M.B.	1000-kernel weight	Yield per acre	Swathing date	K.M.C. at swathing	W.M.B.	1000-kernel weight	Yield per acre	Swathing date	K.M.C. at swathing	W.M.B.	1000-kernel weight	Yield per acre	Swathing date	K.M.C. at swathing	W.M.B.	1000-kernel weight	Yield per acre
	%	lb.	gm.	bu.		%	lb.	gm.	bu.		%	lb.	gm.	bu.		%	lb.	gm.	bu.
July 25	46.1	31.2	24.88	41.5	July 28	44.0	36.1	30.20	15.4	Aug. 3	44.5	32.5	22.67	34.0	July 25	52.8	26.9	19.37	20.9
July 26	43.7	31.9	25.52	37.6	July 29	42.0	35.9	30.55	17.0	Aug. 4	42.6	32.0	22.82	33.3	July 26	51.7	27.7	21.15	20.2
July 27	43.2	32.6	25.45	47.0	July 30	39.1	36.8	30.66	20.3	Aug. 5	43.8	33.1	22.93	35.6	July 27	49.4	24.5	19.97	31.2
July 29	36.6	35.4	26.41	54.4	July 31	36.3	36.8	30.36	24.0	Aug. 6	37.5	34.7	24.21	36.9	July 28	48.0	25.2	21.26	30.6
July 30	39.7	34.1	26.25	47.5	Aug. 1	32.4	35.9	31.17	22.6	Aug. 7	37.7	32.8	25.27	37.1	July 29	45.5	26.4	21.24	37.0
July 31	35.4	36.6	27.39	53.2	Aug. 4	20.0	37.5	31.54	22.9	Aug. 10	25.5	35.0	24.14	41.1	July 30	45.3	27.2	21.21	35.4
Aug. 1	33.9	36.1	27.83	56.3	Aug. 5	19.2	37.9	31.29	21.3	Aug. 11	27.7	34.8	25.24	39.1	Aug. 1	40.4	28.8	23.44	36.1
Aug. 2	32.6	37.2	26.85	51.0	Aug. 6	17.5	36.6	30.27	24.4	Aug. 12	28.3	34.1	24.84	41.0	Aug. 3	34.1	28.7	24.00	40.5
Aug. 3	32.6	36.5	27.10	55.4	Aug. 7	16 3	39 5	30 69	22.7	Aug. 17	22.2	35.2	26.34	43.6	Aug. 4	35.0	29.9	23.84	40.6
Aug. 5	24.3	35.2	28.17	56 5	Aug. 8	17 2	37 8	31.72	26.4	Aug. 18	17.2	35.6	25.22	41.5	Aug. 9	26.4	30.2	24.77	42.2
Aug. 7	21.9	33.0	27.58	51.5	Aug. 11	12.8	38.3	32.56	29.3	Aug. 19	20.2	35.3	25.66	42.1	Aug. 10	26.5	30.9	24.92	45.2
Aug. 8	21.7	35.5	28.01	63.7						Aug. 20	18.5	36.2	23.63	43.5	Aug. 11	25.1	29.9	25.07	40.8
Aug. 9	16.0	32.9	28.60	52.6						Aug. 24	13.0	34.6	24.36	41.8	Aug. 12	22.8	30.2	25.29	44.7
Aug. 12	20.0	36.9	27.75	58.5											Aug. 15	16.0	31.4	24.54	45.3
Aug. 13	14.4	36.1	27.73	56.4											Aug. 16	16.2	32.1	24.45	43.6
															Aug. 17	13.8	31.6	24.51	44.8
L.S.D. P=0.05	3.7	2.2	1.62	8.9		9.4	N.S.	N.S.	N.S.		3.2	N.S.	N.S.	6.3		2.4	1.7	2.21	7.4
S.E.M. %	4.2	2.2	2.11	5.6		4.6	2.8	1.97	15.8		3.8	2.4	4.32	5.6		4.7	3.0	3.42	7.1

The rate of drying (17, 18) was found to be greatest in the swath and least in the standing crop. Swathed grain was ready for harvesting with the combine 5 to 7 days after cutting (14).

PROCEDURE

Garry oats, considered typical of the varieties grown in the Prairie region, was used in all tests. The procedure followed was that outlined in previous papers (4, 5, 6). Kernel moisture content at the time of cutting was used as a measure of maturity.

This field experiment was designed to consist of four blocks, each containing 20 randomized plots, 1 for each swathing date. Swathing was started when the grain approximated 50 per cent kernel moisture and continued daily, weather and field conditions permitting, until the grain reached 14 per cent moisture or less. A self-propelled swather was used throughout the tests, the acreage for calculation purposes being one swath wide by the length of the plot, or approximately 1/25 acre. All sampling for moisture was made from a second adjacent swath, thus not disturbing the first swath which was used for yield determinations.

Kernel moisture was determined immediately after swathing from samples of threshed, cleaned grain. A sample was also collected from each of the previous cuttings and moisture determined to record the rate of drying in the swath.

The swaths reserved for yield determinations were threshed with a combine when the kernel moisture content reached 14 per cent or less. Yield in bushels per acre was calculated on the basis of the standard 34-pound bushel from the recorded weight of grain from each plot. The 1000-kernel weights and weight per bushel were determined from the threshed samples without further processing.

RESULTS AND DISCUSSION

The means of the replicates for bushel weight, 1000-kernel weight, and yield data for the years 1957 to 1960, inclusive, are shown in Table 1. Correlation coefficients between kernel moisture at the time of swathing and bushel weight, 1000-kernel weight, and yield, calculated from these means, are shown in Table 2.

Weight per measured bushel exhibited a trend to increase as the grain matured. An analysis of the data for 1958 and 1959 showed that this increase was not statistically significant. The 1957 data indicate that the bushel weight did not vary significantly after a stage of maturity defined by a kernel moisture content of 35.4 per cent had been reached, except in two instances when a significant decrease was recorded. Bushel weight and kernel moisture at swathing are not significantly correlated for the full range of the test for this year. The data for 1960 revealed that weight per measured bushel varied significantly in only one instance after the kernel moisture reached 35.0 per cent. These two characters were not significantly correlated after the 26.4 per cent moisture stage. Sampling was prevented on August 2 and again between August 4 and 9 by inclement

TABLE 2. — CORRELATION COEFFICIENTS OF KERNEL MOISTURE CONTENT WITH WEIGHT PER BUSHEL, WEIGHT PER 1000 KERNELS, AND YIELD FOR 1957, 1959 AND 1960

Swathing Tests with Garry Oats
Swift Current, Saskatchewan

Year	Kernel moisture correlated with weight per bushel			Kernel moisture correlated with 1000-kernel weight			Kernel moisture correlated with yield		
	Range of kernel moisture	Number tests	r	Range of kernel moisture	Number tests	r	Range of kernel moisture	Number tests	r
1957	46.1–14.4	15	−0.390	46.1–14.4	15	−0.881**	46.1–14.4	15	−0.716**
				33.9–14.4	9	−0.622	36.6–14.4	12	−0.444
1959							44.5–13.0	13	−0.926**
							25.5–13.0	8	−0.511
1960	52.8–13.8	16	−0.911**	52.8–13.8	16	−0.895**	52.8–13.8	16	−0.877**
	26.4–13.8	7	−0.643	40.4–13.8	10	−0.608	35.0–13.8	8	−0.669
All data for all years	52.8–35.0	22	−0.782**	52.8–35.0	22	−0.682**	52.8–35.0	22	−0.428*
	35.0–12.8	33	−0.269	35.0–12.8	33	−0.228	35.0–12.8	33	+0.162

**Significant at P = .01
*Significant at P = .05

weather. It is postulated that the association between moisture and bushel weight would not have been significant at some earlier intermediate stage had there not been the unavoidable date gaps. A correlation of all moisture and all bushel weight data revealed that the association was of a low order after the 35 per cent kernel moisture stage.

The weight per 1000 kernels also increased as maturity advanced. The increase in 1957 was not significant after the 35.4 per cent kernel moisture stage, and moisture and 1000-kernel weight were not significantly correlated after the grain reached 33.9 per cent moisture. There was no significant increase in 1000-kernel weight for the range of the tests in 1958 and 1959. The data from the 1960 tests suggest that 1000-kernel weight was not significantly greater after the 34.1 per cent kernel moisture stage, although a correlation between those characteristics places the moisture at the 40.4 per cent moisture stage. The analysis of the data for all years shows that these characteristics were not significantly correlated with kernel moisture contents below 35.0 per cent.

A correlation between kernel moisture content at swathing and yield for the 1957 data showed that this association was not significant after the moisture reached 36.6 per cent. The analysis of variance places the stage after which yield does not increase at 33.9 per cent kernel moisture even though yield results in three swathing dates disrupt the trend. The data for 1958 show that there was no significant increase in yield over the range of the test. In 1959 the stage of maturity after which the increase in yield was not significant appeared at the 25.5 per cent moisture stage. This was further substantiated by the calculation of the correlation coefficient. However, because of a gap in swathing data between August 7 and 10, it is suggested that this stage might have occurred at some earlier, higher moisture content. The 1960 data indicated that this stage occurred at 34.1 per cent kernel moisture. The correlation calculation places this stage at 35.0 per cent moisture, while an analysis of all the yield data for all years suggests that the cut-off occurs at 35 per cent kernel moisture.

The swaths were well formed and adequately supported on the stubble, as determined by observations during the swathing operation and the subsequent drying period, at all stages of maturity. The extra weight of green material present in the grain cut at high moisture content did not cause the swath to settle any more than that cut at a more mature stage when placed on similar stubble.

It was established from moisture data collected from the cut grain each day that oats, swathed at 35 per cent kernel moisture, could be threshed with the combine 3 to 5 days after swathing if suitable weather conditions prevailed during that period. This is 7 days in advance of the date when oats would be at a suitable stage of maturity for straight combining.

CONCLUSIONS

1. The swathing of oats can be started at a stage of maturity defined by a kernel moisture content of 35 per cent without significant loss of bushel weight or yield.

2. This stage of maturity is developed 10 to 12 days in advance of the condition when oats is ready to be straight combined.
3. Oats cut at a kernel moisture content of 35 per cent may be threshed with a combine after 3 to 5 days in the swath under dry weather conditions.
4. Oats is a crop that matures well in the swath and the cut grain remains adequately supported on the stubble.
5. Swathing at a very early stage of maturity had the effect of depressing the yield as well as producing low quality grain.

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THE CONTROL OF THE APPLE APHID ON DWARF APPLE TREES WITH BARK APPLICATIONS OF DIMETHOATE[1]

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ABSTRACT

Very effective control of the apple aphid, *Aphis pomi* DeG., on dwarf apple trees, has been obtained by two paintings of an undiluted emulsifiable concentrate of dimethoate (30 per cent active ingredient) on the basal part of the trunk of the tree. Approximately 2 millilitres are applied per tree, and application is made with a 1-inch paint brush around the trunk over a distance of approximately 12 inches. A single application in early July, at a time when the seasonal upsurge of aphids is beginning, gave excellent control for 3 to 4 weeks, even where conditions for reinfestation were favourable. A second application at the end of that period ensured full seasonal control. Almost equally good control was obtained by diluting the concentrate with an equal volume of water. At greater dilutions less effective control resulted. The use of a slurry made from dimethoate, 50 per cent wettable powder, in place of the emulsion, was reasonably effective but slower in action.

INTRODUCTION

In a previous paper (7) a general account was given of the usefulness of dimethoate [*O,O*-dimethyl *S*-(*N*-methylcarbamoylmethyl) phosphorodithioate], an orchard insecticide, in British Columbia. The outstanding performance of this systemic insecticide against the apple aphid, *Aphis pomi* DeG., was stressed. A brief comparison was made of the relative merits of dimethoate against that insect when the material was applied to dwarf apple trees: (a) as a dilute foliar spray; (b) as a concentrate painted on the tree trunk; (c) as a concentrate in bandages affixed to the trunk. The foliar spray was less persistent in its effects than the trunk application; and trunk application by bandage was more effective than by brush. However, bandage application was judged to be less feasible, commercially, than application by brush. The work reported here is a more extensive study of the effectiveness of brush application of dimethoate on dwarf trees. Dwarf trees with their smooth, thin bark are peculiarly suited to this form of systemic application.

METHODS AND EXPERIMENTAL CONDITIONS

The experiment was conducted in an orchard of 4-year-old Red Delicious apples on Malling IX rootstock. The trees were approximately 7 feet high at the end of the season. Trunk circumferences varied from 4 to 6 inches. The planting spacing is 10 feet between rows, and 5 feet between trees within the rows. There is a permanent cover crop of white Dutch clover, frequently mowed. Irrigation is by overhead sprinklers. The data used in this study were obtained in 1960 from observations on randomized and replicated blocks involving a total of 200 of these trees. For each treatment there were four plot replications, and five trees in each plot.

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Most of the experiments were carried out with dimethoate diluted from an emulsifiable concentrate that contained 30 per cent of the technical material (Rogor)*. In some experiments technical dimethoate was used dissolved in distilled water. In other experiments a slurry of dimethoate, 50 per cent wettable powder,** was applied to the trees. The emulsifiable concentrate was used undiluted, and diluted with water to make emulsions containing 15, 7.5 and 2 per cent of technical dimethoate. Unformulated technical dimethoate, which is partly soluble in water (1, 3), was dissolved in distilled water to make a 2 per cent solution. The wettable powder was made into a slurry by adding water, equal to one-third of the weight of the powder, and stirring to a thin paste-like consistency. The slurry then contained 37 per cent of active ingredient.

Application was made with a 1-inch paint brush, around the basal part of the trunk of the tree from a height of 12 inches down to ground level. This was done because previous work (7) showed that some dimethoate must be applied below the level at which the lowest branch leaves the main trunk. If the compound is applied above the point at which a branch emerges, aphid control in that branch is delayed. Dimethoate apparently moves upward within the tree much more readily than it does downward.

A graduate cylinder was used to hold the fluid. The volume was noted before and after each group of trees was treated so that an average figure was obtained for the amount applied per tree. The average for all liquid applications was 1.95 millilitres per tree; that is, approximately 1 fluid ounce was used for every 15 trees. The amount of wettable powder applied per tree in the slurry could not be accurately estimated, but was judged to be about 2 grams per tree.

For the assessment of results, the number of aphids in a 25-gram sample of terminal leaves was estimated from a volume measure of all the insects recovered from a sediment in alcohol. Fumes of 4-methyl 2-pentanone were used to induce the aphids to release their stylets from the leaf tissue. The numbers of aphids in one millilitre of alcoholic sediment averaged 2,070. The method has been described in detail elsewhere (6). Weighing of representative samples of leaves showed that terminal leaves of apple (variety, Red Delicious) averaged 0.026 grams per square centimetre. A 25-gram sample, therefore, consists of a leaf area of nearly 1,000 square centimetres.

The experiments were carried out from July 7 to August 31. The mean minimum temperature for the period was 57.3°F., and the mean maximum was 84.1°F. The rainfall totalled 1.13 inches; none of this fell in July, and more than half fell on a single day in late August. The temperature at the actual time of the first application was 94.6°F., and of the second, 84.0°F. The temperatures were recorded in a Stevenson screen approximately 25 yards from the edge of the orchard.

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*Trademark of Montecatini, Italy. Distributed in Canada by Fisons (Canada) Ltd., Toronto, Ont.
**American Cyanamid Co., Stamford, Conn.

TABLE 1.—EFFECT OF SINGLE BARK APPLICATIONS OF DIMETHOATE ON NUMBERS OF APHIDS. EACH FIGURE INDICATED IS THE MEAN NUMBER OF APHIDS FROM FOUR 25-GRAM SAMPLES OF TERMINAL FOLIAGE. WHERE NUMBERS OF APHIDS WERE BELOW 200, THEY WERE COUNTED; ABOVE 200, THEY WERE ESTIMATED ON THE BASIS OF 2,070 APHIDS PER MILLILITRE.

Bark treatment	Percentage of active ingredient	Mean number of aphids per 25 grams of terminal foliage								
		Just before application	Days after application							
			1	2	4	10	21	28	35	45
Emulsifiable concentrate: Undiluted	30.0%	4,374	3,934	2,278	0	0	0	186	1,836	2,168
Diluted 1:1 with water	15.0%	4,104	4,545	2,036	0	0	84	209	1,665	3,321
Diluted 1:3 with water	7.5%	5,173	3,799	4,485	1,861	190	624	1,037	1,248	4,519
Diluted 1:14 with water	2.0%	4,978	5,363	4,781	2,455	404	631	848	2,828	4,913
Technical dimethoate dissolved in water	2.0%	3,921	4,312	5,317	4,308	6,950	7,531	10,101	9,123	11,677
Slurry of dimethoate wettable powder in water	37.0%	4,521	4,832	5,097	4,279	136	2	23	108	456
Check	No treatment	4,347	3,999	4,968	6,385	6,598	7,038	9,541	12,045	10,111

TABLE 2.—EFFECT OF TWO BARK APPLICATIONS OF DIMETHOATE ON NUMBERS OF APPLE APHIDS. THE SECOND APPLICATION OF DIMETHOATE WAS MADE 25 DAYS AFTER THE FIRST. THE MEAN NUMBERS OF APHIDS WERE OBTAINED AS INDICATED IN TABLE 1.

Dilution of emusifiable concentrate	Percentage of active ingredient	Mean number of aphids per 25 grams of terminal foliage								
		Just before application	Days after application							
			1	7	14	20	24	30	37	46
Undiluted	30%	4,008	3,976	0	0	12	89	0	0	0
Diluted 1:1 with water	15%	4,961	5,768	9	0	2	98	0	0	5
Check	No treatment	4,368	4,931	5,361	6,009	9,321	8,911	11,093	13,391	9,081

RESULTS

The results obtained for single applications are shown in Table 1. It is apparent that application of dimethoate emulsifiable concentrate at full- and half-strength gave a remarkable degree of control of aphids for 3 to 4 weeks. The extremely high level of infestation on the check trees throughout the course of the experiment is noteworthy. These check trees provided a ready source of reinfestation for the treated trees, because large numbers of winged forms of aphids were present on them during the course of the experiment. The treatments, therefore, were put to a severe test. In a commercial orchard no such trees would be left untreated. After 5 weeks (Table 1) the systemic insecticide at full- and half-strength had apparently run its full course in the plants, and the upsurge of aphids had recommenced.

Statistical analysis of the data (after logarithmic transformation to better satisfy the requirements for the analysis of variance) also shows significant ($P>0.05$) reduction of aphid populations on the treated trees at the two lowest concentrations of emulsifiable concentrate, from the fourth day onwards. However, though this significant difference indicates that the systemic compound was translocated throughout the plant in sufficient quantity to have an effect on the aphid population, the reduction of the infestation to a level sufficient to constitute commercial control was only briefly attained, or not at all. For effective commercial control the numbers of aphids should remain below 100 per 25-gram sample of terminal foliage.

It is noteworthy that technical dimethoate dissolved in water, at the near saturation level of 2 per cent, was less effective than an equivalent quantity of formulated dimethoate emulsion. Though the latter did not give commercial control the fact stresses the importance of a solvent in facilitating entry into the plant's translocation system. Further emphasis is given to this point by the findings when a slurry of dimethoate wettable powder was used. Here, dimethoate, though present in very considerable quantity, came into action more slowly than when used in an emulsion form; though there is indication that its effects are more persistent (Table 1).

The results obtained with two applications of dimethoate emulsifiable concentrate, undiluted or diluted with an equal volume of water, are shown in Table 2. Excellent control of aphids, surpassing that obtained in previous work with any other aphicide, was achieved throughout the period of greatest apple aphid activity. At the end of the season the difference in growth between treated and untreated trees was very noticeable. The former had made more growth, and their terminal leaves were well formed, soft and pliable. The latter had made much less new growth, the terminal leaves were stunted, tightly curled, stiff, and sticky with honeydew from the large numbers of aphids.

No phytotoxic effect of dimethoate, either directly on the bark, or, through translocation, on leaves was observed in this series of trials; although in an earlier investigation (7), a different formulation of the emulsifiable concentrate did cause minor damage.

DISCUSSION

Although it has been known for some time (4, 5) that bark application of certain systemic insecticides could give control of some pests on fruit

trees the treatment does not appear to have come into commercial use. The experiments reported here suggest that it is a feasible method when employed against the apple aphid on nursery stock or on dwarf trees. Systemic insecticides, applied by any means, have never shown much promise against lepidopterous pests; so that control of the codling moth, *Carpocapsa pomonella* L., the major pest of apple, is likely to be achieved only by non-systemic insecticides. Such insecticides can only be applied by a spray machine. Tetranychid mites, often serious apple pests, are susceptible to attack by systemic methods (4), but unfortunately the most important species in British Columbia have developed resistance to organic phosphate insecticides (2) and are not controlled by dimethoate (7). However, mites are not normally a serious problem on young trees; heavy infestations seem to occur only on bearing trees that have received sprays of DDT [2,2-bis (*p*-chlorophenyl)-1,1,1-trichloroethane] for the control of the codling moth.

On non-bearing trees in British Columbia aphids are generally the only serious pests; on such trees, bark application provides a feasible commercial means of control. The method is economical. The spacing of the trees used in the experiments was 10 x 5 feet; this corresponds to slightly over 1,000 trees per acre. Such dense planting of dwarf trees, though common in Europe, is as yet uncommon in North America. Two applications on bark, of dimethoate emulsifiable concentrate diluted with an equal volume of water, would require 2,000 millilitres, or approximately 3.5 imperial pints (70 fluid ounces) of concentrate per acre. An application of dilute spray, sufficient to reach the run-off point, on dwarf trees 6 feet high, would require about 250 gallons per acre. Two applications, at least, would be necessary since a foliar spray is less efficient than a bark application (7). Perhaps 10 imperial pints of concentrate per acre, nearly three times as much as with bark application, would be necessary to achieve aphid control throughout the season.

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EFFECTS OF AMITROLE, ZYTRON AND OTHER HERBICIDES OR PLANT GROWTH REGULATORS ON THE PEA APHID, *ACYRTHOSIPHON PISUM* (HARRIS), CAGED ON BROAD BEAN, *VICIA FABA* L.

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ABSTRACT

Thirty herbicides or plant growth regulators were tested against the pea aphid, *Acyrthosiphon pisum* (Harris), on broad bean, *Vicia faba* L. When amitrole at 300, 200 and 100 p.p.m. of active ingredient in water was absorbed by the roots, fecundity of the adults was reduced and mortality of their progeny was 100, 100 and 93.9 per cent respectively. No significant effects on fecundity occurred when amitrole was applied to the leaves or as a contact spray on adult aphids. When Zytron at 3,000, 2,000 and 1,000 p.p.m. of active ingredient in water was absorbed by the roots, mortality of adults was 100, 100 and 95 per cent and of their progeny 100, 100 and 98.6 per cent respectively. When Zytron was applied to the leaves at 8,000, 4,000 and 2,000 p.p.m. of active ingredient in water there was a mortality of adults of 85, 70 and 50 per cent and of nymphs 75.1, 45.4 and 29.9 per cent. The lower mortality of nymphs occurred over a 5-day period, indicating that the initial toxic effects from application to the leaves were soon lost. Mortality of nymphs refers to young aphids born alive and killed by the toxic effects of amitrole or Zytron. Twenty-seven of the chemicals showed no effects on aphids caged on treated plants.

INTRODUCTION

A study was begun in 1958 at the University of Manitoba to determine possible effects, either deleterious or beneficial, of herbicides or plant growth regulators on the pea aphid, *Acyrthosiphon pisum* (Harris), caged on treated broad bean, *Vicia faba* L. Continuation of the project was encouraged by the discovery that maleic hydrazide applied by absorption through the roots caused a significant decrease in fecundity of wingless female pea aphids (apterous alienicolae). Preliminary results were reported by Robinson (4,5). Recently Adams (1) reported some mortality to the larvae of three species of coccinellid beetles predacious on aphids on barley when sprayed with 2,4-D and an increase in mean time to pupation in all groups except the 1-day-old larvae. Effects of gibberellic acid on growth and food consumption of *Periplaneta americana* L. were reported by Siakotos and Dewey (6) and on rate of reproduction of *Tetranychus telarius* (L.) by Eichmeier and Guyer (2).

MATERIALS AND METHODS

During this study 30 herbicides or plant growth regulators were applied to broad bean plants by absorption through the roots and by dipping leaves. A wide range of chemicals was tested which included all those at present commonly used or under test in Western Canada. Twenty-seven of the chemicals are shown in Table 1. The other three were amitrole, Zytron and maleic hydrazide. All dosages used are reported as p.p.m. of active ingredient. The plants were grown in soil in the greenhouse until 2-4 inches high and then transplanted to vermiculite in 3½-inch clay pots. The

[1]Part of thesis submitted to the Faculty of Graduate Studies and Research, University of Manitoba, in partial fulfilment of requirements for the degree of Doctor of Philosophy.

TABLE 1.—NAMES OF 27 HERBICIDES OR PLANT GROWTH REGULATORS THAT HAD NO EFFECTS ON PEA APHIDS CAGED FOR 5 DAYS ON TREATED BROAD BEAN PLANTS

Common[1] or trade name	Chemical name[1]	Formulation[2]	Highest rate p.p.m. of active ingredient	
			Root treatment	Leaf treatment
atrazine	2-chloro-4-ethylamino-6-isopropylamino-s-triazine	50% WP	0.01	100
Avadex	2,3-dichloroallyl-diisopropylthiol-carbamate	50% EC	4,000	4,000
barban	4-chloro-2-butynyl-N-(3-chlorophenyl) carbamate	12.5% EC	3,000	8,000
CDAA	2-chloro-N, N-diallyl-acetamide	47% EC	100	1,000
CDEC	2-chloroallyl diethyldithio-carbamate	46.4% EC	100	1,000
chlorazine	2-chloro-4,6-bis (diethyl-amino)-s-triazine	49.5% EC	1,000	1,000
CIPC	isopropyl N-(3-chlorophenyl) carbamate	48% EC	3,000	10,000
2,4-D	2,4-dichlorophenoxyacetic acid	50% EC (amine)	2	1,000
dalapon	2,2-dichloropropionic acid	74% S	1,000	10,000
4-(2,4-DB)	4-(2,4-dichlorophenoxy) butyric acid	40% EC (amine)	100	100
DMTT	3,5-dimethyltetrahydro-1,3-5, 2H-thiadiazine-2-thione	85% WP	100	1,000
DNBP	4,6-dinitro ortho secondary butylphenol	53% EC (amine)	300	1,000
eptam	ethyl N,N-di-n-propylthiol-carbamate	78% EC	100	1,000
erbon	2-(2,4,5-trichlorophenoxy) ethyl 2,2-dichloropropionate	41.3% EC	1,000	10,000
gibberellic acid	potassium gibberellate	94% S	1,000	1,000
IPC	isopropyl N-phenylcarbamate	25% EC	1,000	1,000
MCPA	2-methyl-4-chlorophenoxy-acetic acid	50% EC (amine)	8	10
4-(MCPB)	4-(2-methyl-4-chloro-phenoxy) butyric acid	40% EC (amine)	100	1,000
monuron	3-(p-chlorophenyl)-1,1-dimethylurea	80% WP	1	1,000
NPA	N-1-naphthylphthalamic acid	Alanap-3	1,000	1,000
sesone	sodium 2,4-dichloro-phenoxyethyl sulfate	90% S	1,000	8,000
silvex	2-(2,4,5-trichlorophenoxy) propionic acid	42.5% EC (ester)	100	100
simazine	2-chloro-4,6-bis (ethylamino) -s-triazine	50% WP	1	100
2,4,5-T	2,4,5-trichlorophenoxyacetic acid	42.5% EC (ester)	0.1	0.1
2,3,5,6-TBA	2,3,5,6-tetrachlorobenzoic acid	47.7% EC	100	1,000
2,3,6-TBA	2,3,6-trichlorobenzoic acid	24.8% EC	100	1,000
TCA	trichloroacetic acid	79% S	4,000	10,000

[1] Common and chemical names from *Weeds*, Vol. 8, No. 3, July 1960, p. 490
[2] EC = Emulsifiable concentrate; WP = Wettable powder; S = Soluble powder

treatment by absorption through the roots consisted of standing the pots in a dilute solution for 48 hours. The treatment of the leaves was applied by dipping one of the lower leaves in a dilute solution of the chemical for about 5 seconds to simulate field spraying. In all cases the highest concentrations used gave some visible plant injury such as epinasty, chlorosis or leaf blotching, but not plant death.

Forty-eight hours after application young adult wingless female pea aphids of approximately the same age were caged singly in replicates of 20 on treated plants. They remained on the plants for 5 days in a Coldstream Plant Growth Cabinet at a temperature set to hold at 69°F., average relative humidity of about 70 per cent, with continuous lighting, and a nutrient solution of Plant Prod 20-20-20*. At the end of 5 days counts were made on mortality and fecundity.

Amitrole was applied by absorption through the roots in two separate tests, at rates of 300, 200 and 100 p.p.m., and at 100, 10 and 1 p.p.m., and by dipping leaves in solutions of 300, 200 and 100 p.p.m. Amitrole was also applied as a contact spray on adult aphids at a treatment of 100 p.p.m. Zytron was applied by absorption through the roots at rates of 3,000, 2,000 and 1,000 p.p.m. and by dipping leaves at rates of 8,000, 4,000 and 2,000 p.p.m.

The data on fecundity of aphids in the tests with amitrole were analysed statistically by a transformation using $\sqrt{x + 0.5}$ suggested by Goulden (3).

RESULTS AND DISCUSSION

Of the 30 herbicides or plant growth regulators tested only amitrole, Zytron and maleic hydrazide [see Robinson (4,5)] had any effects on mortality or fecundity of the aphids. The remaining 27 which had no effects are listed in Table 1 with the highest rates of concentrations used.

Table 2 shows that amitrole at rates of 300, 200 and 100 p.p.m. by absorption through the roots caused a reduction in fecundity (total nymphs born) compared with the check, and a mortality of nymphs (total nymphs dead) of 100, 100 and 93.9 per cent respectively. Average number of live progeny of surviving adults differed significantly at the 1 per cent level from the check. Mortality of adults was low. At rates of 10 and 1 p.p.m. no effects on the aphids were noted. When amitrole was applied by dipping leaves in solutions of 300, 200 and 100 p.p.m. there were no effects on the aphids. When this material was applied to aphids as a contact spray at 100 p.p.m., 13 adults died out of 20, but there was no significant difference in fecundity of surviving aphids. These results indicate that amitrole is taken up through the roots of the broad bean plant and acts systemically to reduce fecundity of adults and to cause mortality of nymphs of the pea aphid.

When amitrole was applied to broad beans at 300 and 200 p.p.m., either through the roots or the leaves, plants were severely damaged by the end of one week. At the above rates and at 100 p.p.m. terminal leaves were highly chlorotic. Dosages above 300 p.p.m. killed the plants.

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*Plant Products Company, Port Credit, Ont.

TABLE 2.—MORTALITY OF ADULTS AND NYMPHS, AND PROGENY PER ADULT, AFTER 20 ADULT PEA APHIDS WERE CAGED FOR 5 DAYS ON BROAD BEAN PLANTS TREATED BY ABSORPTION THROUGH THE ROOTS OR BY LEAF TREATMENT WITH AMITROLE OR ZYTRON, OR SPRAYED WITH A CONTACT SPRAY OF AMITROLE

Treatment	Active ingredient p.p.m.	No. of dead adults	Total nymphs born	Total nymphs dead	Live progeny per surviving adult	
					Average	Transformed average[1]
Amitrole[2] (root absorption)	300	3	320	320	0	0.71**
	200	1	473	473	0	0.71**
	100	1	497	459	2.0	1.39**
	Check (Water)	0	662	0	33.1	5.74
Amitrole (root absorption)	100	1	296	267	1.5	1.21**
	10	0	603	0	30.1	5.52
	1	1	635	0	28.2	5.33
	Check (Water)	1	652	0	34.3	5.87
Amitrole (leaf dipping)	300	0	636	0	31.8	5.65
	200	0	635	0	31.7	5.57
	100	0	617	0	30.8	5.56
	Check (Water)	1	565	0	29.7	5.47
Amitrole (contact spray)	100	13	220	0	25.7	5.08
	Check (Water)	4	445	0	27.6	5.14
Zytron[3] (root absorption)	3,000	20	15	15	—	—
	2,000	20	29	29	—	—
	1,000	19	70	69	—	—
	Check (Water)	0	503	32	23.5	—
Zytron (leaf dipping)	8,000	17	205	154	—	—
	4,000	14	271	123	21.5	—
	2,000	10	331	111	21.7	—
	Check (Water)	3	402	18	21.2	—

[1] Transformed by the formula $\sqrt{x+0.5}$
[2] 3-amino-1, 2,4-triazole (25% emulsifiable concentrate)
[3] *O*-2,4-dichlorophenyl O-methyl isopropylphosphoroamidothioate (25% emulsifiable concentrate)
**Significant at the 1% level

When Zytron was applied by absorption through the roots at rates of 3,000, 2,000 and 1,000 p.p.m., mortality of adults was 100, 100 and 95 per cent and of nymphs 100, 100 and 98.6 per cent respectively (Table 2). When Zytron was applied to the leaves at 8,000, 4,000 and 2,000 p.p.m., mortality of adults was 85, 70 and 50 per cent and of nymphs 75.1, 45.4 and 29.9 per cent respectively. The lower mortality of nymphs occurred over a 5-day period, indicating that the initial toxic effects through dipping the leaves were soon lost. Surviving adults reproduced normally and the averages of their live progeny were nearly identical. There was only slight plant injury at the rates used. These results show that Zytron acts on aphids as an insecticide, probably systemic, although there may have been some fumigant action. The insecticidal action of Zytron on ants in lawns has been reported by Watson and Leasure (7).

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THE INFLUENCE OF THE RATIO OF INCANDESCENT TO FLUORESCENT LIGHT ON THE FLOWERING RESPONSE OF MARQUIS WHEAT GROWN UNDER CONTROLLED CONDITIONS[1]

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ABSTRACT

When Marquis wheat is grown under artificial conditions, the main light energy (lamp watts) supplied by fluorescent light should be supplemented by at least 35 per cent of incandescent light in order to have a photoperiodic effect close to the maximal. Increasing the percentage up to 100 per cent resulted in slightly earlier flowering. This effect of incandescent light was caused, not by earlier floral initiation, but by an increase in the rate of stem elongation and a hastening of the later stages of floral differentiation. This action of incandescent light could not be replaced by substituting pink fluorescent for one-third of the white fluorescent lights.

To obtain a photoperiodic effect equal to that of high light energy from combined fluorescent and incandescent bulbs, it is recommended that the daylength be extended by sufficient incandescent light to give an intensity of at least 50 ft.-c. at plant level.

INTRODUCTION

The feasibility of providing controlled conditions of light intensity, temperature and humidity suitable for the growth of plants has been mainly dependent on the development of lamp types that provide sufficiently high illumination without excessive heating effects. Early types of growth chambers, such as those of Davis and Hoagland (4) and Bakhuyzen (1), used incandescent lamps, which needed cooling by either water baths or rapid forced air ventilation. Sodium and mercury vapour lamps were more efficient in light output, as used by Arthur and others (3) in a long series of experiments carried out at the Boyce Thompson Research Institute. In some cases, however, under continued use, these types of illumination caused undesirable side effects such as leaf crinkling, probably because of the limited spectral range of the light provided. It was not until the advent of the fluorescent tube, combining the high efficiency of the mercury vapour lamp with spectral characteristics approximating those of sunlight, that large installations such as those of Went at Pasadena (16) became widespread. It was observed (2) that the flowering behaviour of plants grown under white fluorescent light was not the same as that of plants grown in sunlight, but that the addition of a small proportion of incandescent light could greatly improve the photoperiodic effectiveness of the fluorescent lamp.

The following experiments were undertaken to determine the relative energies of the two lamp types that must be provided to obtain a maximal photoperiodic effect during the growth of Marquis wheat under artificial illumination.

MATERIALS AND METHODS

Marquis wheat from foundation stock supplied by the Genetics and Plant Breeding Research Institute, Canada Department of Agriculture,

[1]Contribution No. 104 from the Plant Research Institute, Research Branch, Canada Department of Agriculture, Ottawa, Ont.

Ottawa, Ont., was grown in sand culture in 1-gallon glazed pots (6). Silica sand, 24-mesh, was sub-irrigated four times daily with Hoagland's No. 1 solution (9) modified by providing the 10 p.p.m. Fe as Sequestrene (sodium ferric ethylenediamine tetra-acetate). This type of culture has been found to provide very good growth, the dry weight increases of the plants being greater than those grown in a well-fertilized John Innes potting soil. The pH was held close to 5.6 and the nutrient solution was renewed weekly.

Light was provided by General Electric 96T8 standard cool white slimline fluorescent tubes (called "white fluorescent" in this paper). Twenty-four tubes, 8 feet long, made up a light panel 3 feet wide. The tubes were spaced a half-inch apart and were separated from the growth room by a sheet of glass. The light panel was ventilated by electric fans drawing air across the tubes so that they operated at a temperature optimal for light output. Where incandescent light was provided, it was given by General Electric frosted incandescent bulbs placed above the fluorescent tubes, in two evenly-spaced rows of five. Energy values given in Table 1 refer to the light received at the top of the plants growing beneath the light panel. These were taken with a Kipp and Zonen No. G2 Solarimetric Thermopile. In Experiment 2B the energy in various spectral regions (Table 3) was measured by an instrument designed by G. W. Robertson, Agrometeorologist of the Plant Research Institute. Under a cosine light receptor a set of filters can be conveniently switched in turn across a photocell so that readings of energy values in five regions of the visible spectrum can be taken with a galvanometer. The narrow spectral bands are isolated by interference filters, as shown in Table 3. The values of the energy in these bands are given in Table 3 together with the ratio of energy in the red and far-red region for the range of light combinations used. These values were determined by correcting for the transmission of the filters and the response of the photocell.

The light intensity at the top of the plants was maintained at the required level by weekly adjustment of their distance from the light panel. The total radiation received by any one pot in the course of an experiment usually varied less than 2 per cent from the stated value. Mean temperatures varied not more than about 1 centigrade degree, and were measured at the top of the plants by unshaded copper-constantan thermocouples. Such measurements closely follow those obtained by insertion of a micro-thermocouple into the leaf tissue. The relative humidity was maintained at about 70 per cent in all experiments.

In most experiments the course of floral initiation was followed by periodical dissections and microscopic examinations of the growing point of the main shoot. A numerical scoring system was developed, similar to that used by Gregory and Purvis (7) for the statistical treatment of developmental stages in rye. 'Score units' express the number of days taken by plants grown under optimal photoperiodic conditions to reach the same morphological stage of development as the sample of plants in question. The optimal conditions for early flowering found in preliminary experiments, were at 30°C. under a photoperiod of 24 hours. Under Table 2 the more important of these morphological stages are listed opposite the corresponding scores.

TABLE 1.—ENERGY LEVELS IN EXPERIMENT 1

Type of light	Lamp wattage per square foot of light panel	Illumination at plant level ft.-c.	Total energy at plant level gm. cal. (cm^2.min)-1
White Fluorescent	73	1,500	.09
White Fluorescent Incandescent	73 31	1,420 80	.08 .08
Total	104	1,500	.16
⅔ White Fluorescent ⅓ Pink Fluorescent	48.7 24.3	— —	— —
Total	73	1,500	.10
ENERGY LEVELS IN EXPERIMENT 2			
White Fluorescent	73	1,780	.12
25 Watt Incandescent	10	20	.04
Total	83	1,800	.16
White Fluorescent	73	1,750	.12
60 Watt Incandescent	25	50	.05
Total	98	1,800	.17
White Fluorescent	73	1,710	.10
100 Watt Incandescent	42	90	.09
Total	115	1,800	.19
ADDITIONAL LEVELS IN EXPERIMENT 2B			
White Fluorescent	73	1,800	.11
White Fluorescent 40 Watt Incandescent	73 17	1,770 30	.12 .05
Total	90	1,800	.17
White Fluorescent 200 Watt Incandescent	73 83	1,620 180	.09 .18
Total	156	1,800	.27

RESULTS

Experiment 1: The Hastening of Anthesis in a 24-hour Photoperiod by Addition of Incandescent Light to Fluorescent Light, and the Effect of Supplementing White Fluorescent Light with Pink Fluorescent Light

Plants were grown at a constant temperature of 20°C. under 1,500 ft.-c. of either white fluorescent light alone or fluorescent plus 80 ft.-c. incandescent light provided by 75-watt reflector bulbs. Energy levels at the top

TABLE 2.—THE EFFECT OF ADDING DIFFERENT LEVELS OF INCANDESCENT LIGHT ON THE FLORAL DEVELOPMENT OF MARQUIS WHEAT GROWN UNDER FLUORESCENT LIGHT IN A 24-HOUR DAYLENGTH

Age of plants, days	Incandescent added		
	20 ft.-c.	50 ft.-c.	90 ft.-c.
	Score units		
7	vegetative		
12	12.0[1]	11.8	11.7
14	12.7	13.0	13.2
21	17.6	18.6	19.4
28	22.3	24.4	24.5
35	28.5	29.1	30.0
42	30.3	32.9	34.5
	45.4	43.7	
Days to heading[2]			41.6 } S.E.
Days to anthesis	47.7	46.0	43.9 } ±.41

[1]Number of replicates 12
[2]Number of replicates 20

Score	Morphological Stage
12	Double ridges on apical meristem, the first sign of floral initiation.
16	Floral ridges swelling.
20	Stamen initials present.
24	Stamen initials become lobed.
28	Secondary bracts elongate, rapid extension of stem tip.
32	Ear at top of leaf sheath.
36	Peduncle elongates.
38	Anthesis.
38+x	x days past anthesis.

of the plants are given in Table 1. In this experiment the effect of light was combined with the effect of type of sand and type and number of daily irrigations of nutrient solutions. The figures for light treatments presented here are the mean values from these various combinations. Dates of anthesis were recorded, and the values subjected to an analysis of variance. Plants grown under fluorescent light alone, anthesed in 67.6 ± 0.46 days, while those given incandescent light in addition, anthesed in 57.3 ± 0.46 days. The addition of incandescent light hastened flowering by 10 days.

In the same experiment another light variant was used in which one-third of the white fluorescent tubes were replaced by pink tubes. The ft.-c. intensity was maintained the same as in the other two variants, which resulted in a slight increase in the total energy over that of white fluorescent alone, (Table 1). Incandescent light was omitted from this treatment. The time taken to anthesis was 67.8 days ± 0.46, and did not differ significantly from that in the panel given only white fluorescent light.

Experiment 2A: Effect of Increasing the Levels of Incandescent Light added to White Fluorescent Light in a 24-hour Daylength

Plants were grown at a constant temperature of 25°C.; light was provided by white fluorescent light supplemented by one of three levels of incandescent light. The levels of incandescent light used were 20, 50 or 90 ft.-c., with

TABLE 3.—ENERGY IN VARIOUS PARTS OF THE SPECTRUM FOR LIGHT TREATMENTS IN EXPERIMENT 2B

Spectral region[1] (peak) Type of light	344 mμ	440 mμ	532 mμ	640 mμ	740 mμ
	Energy, g-cal. ($cm^2.m\mu.10^{-6}$)$^{-1}$				
A. White fluorescent[2]	1.53	33.2	24.8	19.9	2.11
B. plus 25 watts incandescent	1.60	34.9	25.7	20.7	2.77
C. plus 40 watts incandescent	1.81	32.2	27.3	22.3	3.77
D. plus 60 watts incandescent	2.14	38.9	28.7	23.5	4.60
E. plus 100 watts incandescent	1.76	37.2	27.7	24.5	6.99
F. plus 200 watts incandescent	1.62	35.2	27.0	25.0	10.4
Noon sunlight	56.8	201	198	173	136
Green shade of plants	5.5	14.1	14.5	11.0	15.6

[1]Interference filters with 95% of energy transmitted 35 mμ from stated peak
[2]Values for wattage per light panel, etc., in Table 1

	Ratio of energy compared with 532 mμ				Ratio of energy in red to far-red
	344 mμ / 532	440 mμ / 532	640 mμ / 532	740 mμ / 532	640 mμ / 740
A. White fluorescent	.06	1.3	.92	.19	9.4
B. plus 25 watts incandescent	.06	1.4	.81	.11	7.5
C. plus 40 watts incandescent	.07	1.2	.81	.14	5.9
D. plus 60 watts incandescent	.07	1.4	.82	.16	5.1
E. plus 100 watts incandescent	.06	1.3	.88	.25	3.5
F. plus 200 watts incandescent	.06	1.3	.93	.38	2.4
Noon sunlight	.29	1.0	.87	.69	1.3
Green shade of plants	.38	1.0	.76	1.1	.70

wattages of 25, 60, and 100 respectively. White fluorescent light brought the total intensity up to 1,800 ft.-c. at the top of the plants. Energy values are given in Table 1.

Plants were dissected during growth and all stages of development were slower in the 20 ft.-c. series (Table 2). The values for the 90 ft.-c. series were in general higher than those for the 50 ft.-c. series, but not significantly so. The results of an analysis of variance showed that heading and anthesis were significantly advanced in the 90 ft.-c. series, although only by about 2 days.

Experiment 2B

This experiment was similar to the preceding but a wider range of additional incandescent light was used. The combined fluorescent and incandescent light was maintained at 1,800 ft.-c., as before. The temperature was 23°C. The energy levels in five regions of the spectrum are given in Table 3, together with the ratio of energy in the red to the far-red.

The results of periodical dissections (Table 4) show that, although there was very little difference in the time of formation of double ridges (the first sign of a change from the vegetative to the flowering condition), differences between the later stages of floral differentiation became increasingly

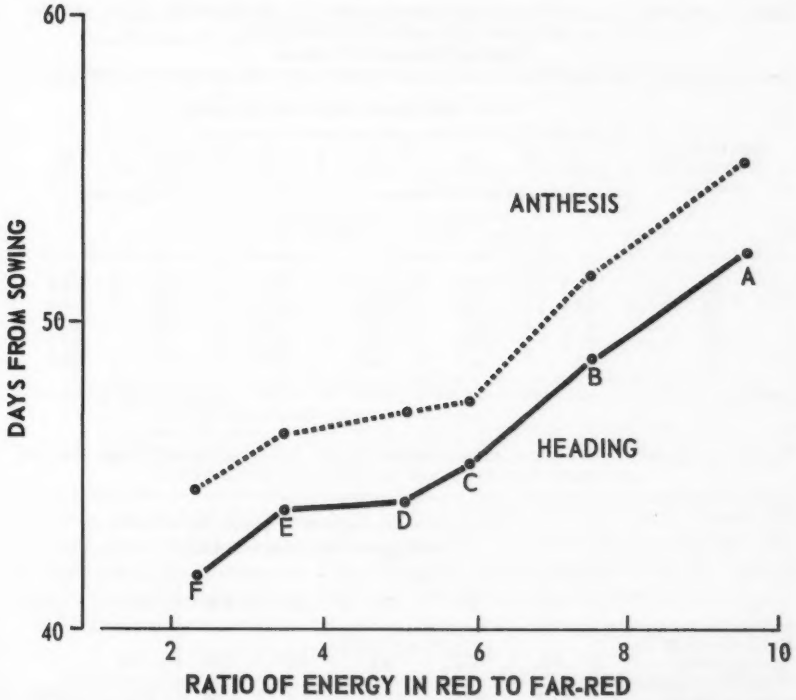

FIGURE 1. The time taken to reach the stages of heading and anthesis under different ratios of red to far-red energy, obtained by supplementing fluorescent light with different levels of incandescent light. A-F, types of light given in Table 3.

apparent. The anthesis of plants given 200-watts incandescent light was 11 days earlier than that of plants given fluorescent light alone. The flowering response was related to the ratio of red to far-red light, as shown in Figure 1; with an increase in the ratio, flowering was progressively delayed. The total dry weight of the plant was not significantly affected by light treatment at the time of the final harvesting after 60 days' growth (Table 5). The earlier flowering in the plants given additional incandescent light was reflected in the greater number of ears emerged and the greater weight of ears. The height of the main stem was also significantly greater. The number of fertile spikelets on the main shoot was greater in the plants given low levels of incandescent light; presumably the longer period of active growth before the dying down of the leaves at about the time of anthesis had allowed these ears to continue growth.

Experiment 3: The Use of Incandescent Light to Extend the Photoperiod of Fluorescent Light

The following experiment was undertaken to determine whether the same level of photoperiodic induction would be obtained when part of the

TABLE 4.—EFFECTS OF ADDING INCANDESCENT LIGHT TO FLUORESCENT LIGHT ON THE PROCESS OF FLORAL DIFFERENTIATION

Values are means of 20 plants

Age of plant in days from sowing	Wattage of Incandescent Added					
	0	25	40	60	100	200
	Score Units					
12	12.3	12.6	12.8	12.4	12.9	12.9
15	13.4	14.0	14.6	14.3	14.0	14.1
18	14.2	14.8	15.9	15.6	15.3	16.3
22	17.3	17.0	18.3	18.2	—	19.3
32	32.3	32.7	34.7	35.1	34.9	38.1

TABLE 5.—EFFECTS OF ADDING INCANDESCENT LIGHT TO FLUORESCENT LIGHT ON THE FLOWERING BEHAVIOUR AND WEIGHT OF MARQUIS WHEAT

	Values are means from 20 plants, 60 days old Wattage of Incandescent Added[1]						
	0	25	40	60	100	200	S.E.
Ratio of energy in red to far-red	9.7	7.7	6.1	5.3	3.6	2.5	
Total dry weight, gm. per plant	12.2	10.5	11.0	13.3	12.6	12.4	±.83
Dry weight of ears, gm. per plant	1.4	1.2	1.9	2.9	2.8	2.7	±.24
Number of ears emerged per plant	7.7	7.1	8.5	10.0	10.0	9.1	±.61
Number of spikelets[2] per ear on main shoot	17.1	14.4	12.5	13.4	11.3	11.5	±.60
Height of main stem, cm.	69	71	72	75	74	84	±1.3

[1]Wattage of incandescent lights per 2.4 square ft. of white fluorescent tubes spaced ½-inch apart
[2]Number of potentially flowering spikelets

light cycle was given as incandescent light alone. Plants were grown at a constant temperature of 20°C. with an illumination of 1,800 ft.-c. of combined fluorescent and incandescent light; the level of incandescent was 50 ft.-c. The energy levels were the same as treatment 2, in Experiment 2A, Table 1. One series was given an 8-hour daylength, another a 16-hour daylength and a third an 8-hour daylength supplemented by 8 hours of incandescent light alone. This supplemental light was given either before or after the main 8-hour light period, making the total photoperiod 16 hours.

The addition of 8 hours of incandescent light hastened all stages of flowering above that of the treatment given 8 hours of combined fluorescent and incandescent light (Table 6). When this supplementary light was

TABLE 6.—PHOTOPERIODIC EFFICIENCY OF 60 FT.-C. INCANDESCENT LIGHT USED TO EXTEND AN 8-HOUR HIGH LIGHT PERIOD OF INCANDESCENT PLUS FLUORESCENT LIGHT

Age of plant, days	Light treatment*			
	A	B	C	D
	Score units			
7	vegetative			
12	vegetative			
14	veg.	11.8	11.3	11.7
21	11.1	14.2	12.0	13.2
28	11.0	18.8	14.3	15.3
35	12.9	21.1	17.1	18.6
36	12.4	—	—	—
42	13.0	—	26.7	28.4

*Light treatments:
A. 8 hours fluorescent plus incandescent / 16 hours dark
B. 8 hours fluorescent plus incandescent / 8 hours incandescent / 8 hours dark
C. 8 hours fluorescent plus incandescent / 8 hours dark / 8 hours incandescent
D. 16 hours fluorescent plus incandescent / 8 hours dark

given at the end of the main light period (treatment B), development was slightly ahead of the 16-hour treatment with combined incandescent and fluorescent light (treatment D). Eight hours of incandescent light given before the main light period was not as effective (treatment C).

DISCUSSION

In this paper the spectral region 'red' refers to wavelengths close to 650 mμ, 'far-red' to wavelengths close to 750 mμ, and 'infra-red' to regions greater than 800 mμ.

It was shown in Experiment 2 that the hastening of flowering by addition of incandescent light was brought about by an acceleration of stem growth and the later stages of ear development, rather than by earlier floral initiation. Under conditions of continuous illumination, floral initiation of Marquis wheat was not influenced by wide changes in the ratio of energies in the red and far-red. It has been shown by Meijer (12) that the reversible photomorphogenic light reaction (8) controlling flowering in many plants does not simply depend on the ratio of light in the two wavelengths red and far-red. While flowering was induced in plants of *Nasturtium palustre* grown in long days at an intensity of 450 μW/cm.^{2} of green plus far-red light, they remained vegetative with red light of equal energy. If the red light was increased to 700 μW/cm.^{2}, the plants flowered. It seems probable in our experiment that the absence of any effect of a wide change in the ratio of red to far-red light was caused by the relatively high intensities employed, so that the reversible red/far-red light reactions were no longer the main controlling agent for floral initiation.

The marked effect of incandescent light in hastening developmental stages after floral initiation was related to the ratio of energies in the red and far-red. A similar relationship has been noted by Stolwijk, (15) working on the elongation of internodes of Salvia. The promotion of stem elonga-

tion by far-red light, especially in rosette plants, has been reviewed by Lona (11). He points out that there is often a parallel between the actions of far-red light and those of applied gibberellin. It is of interest that, like far-red light, gibberellin promotes stem growth and the later stages of flowering rye (13) but is without effect on the time of floral initiation.

As an increase in the level of energy in the red, obtained by substituting pink fluorescent light for one-third of white fluorescent, did not lead to earlier flowering (Experiment 1), the high energy in the far-red was probably the cause of the earlier flowering brought about by addition of incandescent light, (Experiments 2A, 2B). Since the energy in the infra-red, as well as that in the far-red, increased from variant B to F (Table 3), the earlier flowering obtained by addition of incandescent light could also have been caused by the increased energy in the infra-red. It has been reported by Smith (14) that infra-red radiation (wavelengths greater than 1.2 μ) strongly promoted stem elongation and flowering in radish and lettuce. He grew plants at a temperature of 16°C. under continuous illumination with the following types of light: (a) unfiltered light from a panel of eight 200-watt incandescent lamps; (b) light filtered through plate glass; (c) light filtered through plate glass plus 1 cm. water; (d) light filtered through plate glass plus 5 cm. water. The water was used to absorb wave lengths greater than 1.2 μ. Intensities were adjusted to give equal energy values at plant level in the visible region of the spectrum. The days taken to form just visible flower-stems were (a) 29 ± 0.2, (b) 32 ± 0.7, (c) 48 ± 0.6, (d) 51 ± 0.3. Infra-red radiation also affects the flowering of *Lemna* (10).

It seems probable however, that the high far-red energy in the added incandescent light was responsible for the increased stem elongation and earlier flowering in our experiments, as a similar effect of 5 minutes' far-red radiation given after a 16-hour period of fluorescent light occurs in Siberian millet (5). In this case shorter wavelengths were removed by cellophane filters and longer wavelengths by a water screen.

It is interesting to note that the red to far-red ratio in full sunlight is 1.3 (Table 3). If anthesis is controlled by the red to far-red ratio, we should, therefore, expect still earlier flowering in full sunlight than under the fluorescent light plus 200 watts incandescent for the same daylength. Because of the difficulties of maintaining a constant temperature and especially a constant light intensity using sunlight, this comparison has not been made. The ratio of energy in the red to far-red is even lower in green shade, because of the stronger absorption of the red than the far-red by leaves (Table 3), which may be of ecological importance.

From Experiment 3 it was seen that extending the daylength with 50 ft.-c. of incandescent light was sufficient to obtain a photoperiodic effect equal to that of combined high intensity fluorescent light and incandescent light. This low intensity supplementary light was most effective when given after the main light period, as is usual in photoperiodic studies.

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FIELD TESTS WITH *BACILLUS THURINGIENSIS* BERLINER AND DDT FOR CONTROL OF TWO PESTS OF CABBAGE[1]

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ABSTRACT

At Kentville, Nova Scotia, during 1960, seven spray schedules including a commercial preparation of *Bacillus thuringiensis* Berliner and DDT were evaluated in the field for control of the imported cabbageworm, *Pieris rapae* (L.), and larvae of the diamondback moth, *Plutella maculipennis* (Curt.). Up to three spray treatments were applied at 2-week intervals. Three applications of *B. thuringiensis* or one application of DDT followed by two of *B. thuringiensis* gave good control of both insects. In general, DDT and *B. thuringiensis* were equally effective against imported cabbageworm but DDT was more effective against larvae of the diamondback moth.

INTRODUCTION

The use of DDT or other insecticides having a similar lengthy residual toxicity is not recommended within 30 days of harvest for controlling pests of cabbage foliage. If an insecticide is needed in this period it is customary to use one having a low mammalian toxicity such as rotenone, or a short residual toxicity such as malathion. Microbial insecticides, which are not toxic to mammals, may also be used during this period or throughout the season if they are sufficiently effective.

During 1960, several spray schedules using a commercial preparation of *Bacillus thuringiensis* Berliner, DDT, and rotenone were evaluated for control of the imported cabbageworm, *Pieris rapae* (Linnaeus), and the diamondback moth, *Plutella maculipennis* (Curtis).

MATERIALS

A wettable powder preparation of *B. thuringiensis*[3] containing 30 x 10^9 viable spores per gram was applied at a rate of 1.0 pound per acre.

DDT[2] was applied as a 50 per cent wettable powder at the commonly recommended rate of 2 pounds per acre.

Rotenone[4] was applied as a 5 per cent emulsible concentrate at the rate of 34 fluid ounces (imperial) per acre.

A detergent[5] was used at the rate of 0.25 millilitres per gallon (imperial) with all sprays containing *B. thuringiensis*.

METHODS

Danish Ballhead cabbage was grown in square-rod plots separated by 3-foot unplanted margins. There were three replicates for each treatment in the randomized block design. Plants were spaced at 16 inches, in rows 30 inches apart. When the cabbage heads began to form in late July the spray program shown in Table 1 was begun. One gallon of suspension, prepared immediately before use, was applied to each plot with a compressed air hand-sprayer. Twelve plants in the three middle rows of each plot were used for larval counts. Larvae of the diamondback moth and of the imported cabbageworm regardless of size were counted weekly for 7 weeks.

[1]Contribution No. 1053, Research Station, Canada Department of Agriculture, Kentville, N.S.
[2]Thuricide, Stauffer Chemical Co., Mountain View, Calif.
[3]Niatox, Niagara Brand Spray Co., Ltd., Burlington, Ont.
[4]Derrisol, William Cooper and Nephews, Inc., Chicago, Ill.
[5]Triton B-1956, Rohm and Haas Co., Philadelphia, Pa.

TABLE 1.—RESULTS OF A TEST COMPARING SPRAYS OF *B. THURINGIENSIS* (B.T.) AND DDT APPLIED TO CONTROL IMPORTED CABBAGEWORM AND DIAMONDBACK MOTH

Sprays and date applied[1]			Mean number of larvae per 12 plants on 7 recording dates[2]													
			Imported cabbageworm							Diamondback moth						
July 25	Aug. 8	Aug. 22	July 29	Aug. 5	Aug. 12	Aug. 19	Aug. 26	Sept. 2	Sept. 9	July 29	Aug. 5	Aug. 12	Aug. 19	Aug. 26	Sept. 2	Sept. 9
B.t.	—	—	6	14	15	11	33	51	116	17	34	30	32	62	61	59
B.t.	B.t.	—	4	10	5	6	12	48	115	14	19	24	14	24	45	44
B.t.	B.t.	B.t.	8	8	9	10	8	11	18	15	24	32	33	21	23	14
—	B.t.	—	51	48	12	6	19	59	145	31	40	31	25	34	70	41
DDT	DDT	Rotenone	11	15	2	6	14	39	70	5	2	2	2	6	16	9
DDT	B.t.	—	8	12	4	5	13	49	98	3	5	6	6	19	34	24
DDT	B.t.	B.t.	10	11	3	3	7	13	20	3	3	3	6	8	13	10
Untreated	check		58	60	18	18	44	106	151	24	36	64	51	65	54	58
L.S.D. 5%			16	16	8	4	12	29	51	10	14	21	8	15	25	28

[1]B.t. was applied at 1 pound wettable powder per acre; DDT was applied at 2 pounds 50% wettable powder per acre
[2]Mean of three replicates calculated to nearest whole number

RESULTS AND DISCUSSION

None of the spray schedules tested (Table 1) eliminated either the imported cabbageworms or larvae of the diamondback moth. However, the pests were adequately controlled by two spray schedules, namely: three applications of *B. thuringiensis*, or one application of DDT followed by two of *B. thuringiensis*. Although mortality of the cabbageworms was high immediately following one or two applications of *B. thuringiensis*, the plants were not protected for a sufficiently long period. Likewise, a single application of DDT followed by one application of *B. thuringiensis* did not protect plants up to the time of harvest. Rotenone applied late in the season gave adequate control of the diamondback moth but not of the imported cabbageworm.

In general, DDT and *B. thuringiensis* were equally effective against the imported cabbageworm, but DDT was more effective against the diamondback moth.

Although the effectiveness of *B. thuringiensis* against the insects studied was not outstanding the control was acceptable and demonstrated the potential usefulness of the bacteria as an alternative to DDT or rotenone. The results are of particular interest at a time when it is becoming increasingly difficult to comply with residue tolerances of insecticides toxic for mammals. Furthermore, as suggested by Genung (1) the combined use of chemical and biological insecticides may slow the development by insects of resistance to chemicals in common use.

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EFFECT OF SPECKLED LEAF BLOTCH, *SEPTORIA PASSERINII* SACC., ON THE YIELD AND MALTING QUALITY OF BARLEY[1]

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ABSTRACT

In 2 out of 5 years artificial inoculation of barley in field plots at Winnipeg, Manitoba, with speckled leaf blotch (*Septoria passerinii* Sacc.) caused statistically significant yield reductions of about 20 per cent. In 2 other years, inoculated plots yielded less than the check plots but the differences were not statistically significant. Tests on the malting quality of the grain from diseased and check plots of the last trial showed that the disease adversely affected the suitability of the barley for malting. Kernel shrinkage caused by the disease increased cleaning losses and reduced the amount of malt extract.

INTRODUCTION

Speckled leaf blotch of barley, also known as Septoria leaf blotch (*Septoria passerinii* Sacc.), occurs commonly in the cereal-producing areas of central North America and is presumed by some authors to cause important losses (1, 2, 3). Experimental evidence of the destructive capability of the disease has been lacking and there has been skepticism of its economic importance. The results of 5 years of field trials at Winnipeg are presented here to help resolve the uncertainty concerning the potential importance of the disease.

MATERIALS AND METHODS

Successful field experiments were carried out in 1952, 1954, 1955, 1956, and 1959. The 1952 experiment consisted of early inoculated, late inoculated, and check plots replicated three times. Each plot consisted of three rod rows; the centre row of each plot was harvested for yield determinations. In 1954, 1955, and 1956 the design was similar to that of 1952, except that the plot size was increased from three to four rows, the two centre rows being harvested, and the number of replicates was increased from three to six. In 1959 ten pairs (check and inoculated) of 4-row plots were sown. In all years except 1959 the barley plots were separated by two rows of spring wheat to limit spread of the disease from inoculated to check plots. In 1959 the barley plots were separated by two rows of spring-sown winter wheat which also facilitated inoculation and observation of the plots.

No attempt was made to protect the check plots from speckled leaf blotch by application of a fungicide. Several other diseases of barley are prevalent in the Winnipeg area and treatment with a fungicide might have reduced their effect on the check plots. Fortunately, damaging infections of any disease other than speckled leaf blotch did not occur. Light infections of net blotch (*Pyrenophthora teres* (Died.) Drechs.), spot blotch (*Cochliobolus sativus* (Ito and Kurib.) Drechs. ex. Dastur), leaf rust (*Puccinia hordei* Otth.), and stem rust (*Puccinia graminis* Pers.) occurred uniformly throughout the plots in most years. The decision not to apply a fungicide increased the risk of an unsuccessful experiment and may have reduced differences in yield between check and inoculated plots, but it ensured that any difference in yield was caused only by speckled leaf blotch.

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[2]Plant Pathologist, and Cereal Chemist, respectively.

TABLE 1.—AVERAGE DISEASE RATINGS AND YIELDS OF BARLEY AFTER INOCULATION WITH SPECKLED LEAF BLOTCH, AT WINNIPEG, MANITOBA

Year	Variety	Average disease rating[1]			Average yield in grams			Yield as per cent of check	
		Early inoculation	Late inoculation	Check	Early inoculation	Late inoculation	Check	Early inoculation	Late inoculation
1952	Vantage	67	68	12	640.3	572.0	663.0	96.6	86.3
	Montcalm	80	77	12	477.3	489.3	540.0	88.4	90.6
1954	Vantage	52	22	6	494.6**	495.3**	619.0	79.9	80.0
1955	Montcalm	50[2]	34[2]	14[2]	445.0	439.6	439.8	101.2	99.9
1956	Parkland	63	68	52	474.3	458.5	490.0	96.8	93.6
1959	Parkland	83	—	3	1390.0*	—	1720.0	80.8	—

[1]Percentage leaf blades affected, except in 1954 when ratings we.e made on leaf sheaths. Leaf sheath ratings are often lower than leaf blade ratings at Winnipeg. The 1954 ratings are not comparable with those of other years.
[2]Plots badly lodged and most leaves dead from causes other than speckled leaf blotch when severity of infection was estimated.
**Significantly lower than the yield of the check at the 1% level
*Significantly lower than the yield of the check at the 5% level

Cultures of *Septoria passerinii* collected on barley in Manitoba were used to produce inoculum. Conidia were produced in quantity by growing the fungus on potato-sucrose-agar. Plants were inoculated by spraying with a water suspension of conidia with 0.5 per cent gelatin added as a sticker. Early inoculations were carried out at about the flag leaf stage and late inoculations were carried out after the plants headed.

Well-known commercial varieties of barley were used (Table 1). The feed variety Vantage is very susceptible to speckled leaf blotch and it is resistant to stem rust; the malting variety Montcalm is slightly less susceptible to speckled leaf blotch than Vantage and it is susceptible to stem rust; Parkland, a recently introduced malting variety, is susceptible to speckled leaf blotch and resistant to stem rust.

Malting quality studies were made on the barley grown in 1959. Test samples of about 400 grams were taken from six pairs of plots selected at random. The samples were malted at the Canada Department of Agriculture Research Station, Winnipeg, and the malts were analysed for principal quality criteria by standard procedures.

RESULTS

The summarized results of the experiments (Table 1) show that speckled leaf blotch reduced yield in 2 out of 5 years. The absence of a yield loss in 1955 can be attributed to an early and poor crop, to delayed inoculation which resulted in a less severe infection than in most other years, and to the natural development of the disease in the check plots. The failure to demonstrate a statistically significant yield reduction in 1952 may have resulted from insufficient replication. In 1956 a severe natural infection developed and the difference between the amount of infection in check and inoculated plots was not great. In 1954 and 1959 significant yield reductions of about 20 per cent occurred. In both years the inoculated plots were severely infected while the check plots were lightly infected. There was a sharp reduction in kernel weight in 1959 but not in 1954.

The results of the experiment in 1959, in detail, are:

	Check plots	Inoculated plots
Yield, uncleaned (grams)	2117	1665
Yield, cleaned (grams)	1720	1390
Disease rating (leaves)	3.2	83.0
Disease rating (stems)	4.8	81.5
Light kernels cleaned out (grams)	14.9	23.4
Weight per 1000 kernels (grams)	35.2	30.2
Weight per bushel (pounds)	46.4	42.3

The disease sharply reduced yield, kernel weight, and measured bushel weight. After the grain was cleaned the light kernels in the screenings were separated from the chaff. The larger quantity of light kernels cleaned out of the grain from the inoculated plots, as well as the reduced 1000-kernel and bushel weights of this grain, demonstrate that the disease can sharply reduce kernel plumpness.

TABLE 2.—MALTING TEST DATA ON BARLEY FROM DISEASED AND CHECK PLOTS (MEAN VALUES FROM SIX PAIRS OF SAMPLES)

Quality factor	Check plots	Diseased plots
Barley		
Heavy grade[1], per cent	96.1	79.6
1000-kernel weight (dry basis), grams	32.9	28.8
Nitrogen, per cent	2.31	2.24
Malt		
Extract, per cent	73.6	73.0
Soluble nitrogen, per cent	0.99	1.04
Diastatic activity, degrees L.	135	137

[1] Barley retained by 5/64-inch screen, i.e., that normally used for malting. The 1000-kernel weight measurement is made on this barley.

In view of the striking differences in physical properties between grain from the check and inoculated plots in 1959, possible accompanying differences in malting and malt properties were investigated. The results of barley and malt analyses are given in Table 2. The two sets of samples did not differ significantly in barley nitrogen content and there appeared to be no difference in their ability to germinate during malting nor in other observable malting process characters. Measurements of enzymatic activity made on the finished malts, such as soluble nitrogen content and diastatic (saccharifying) activity, indicated an equal ability to achieve the modification from barley to malt in both sets of samples. There was, however, a significantly lower amount of total extractable matter in the malt made from the diseased plot samples. This is related to the difference in kernel size between the sets of samples, which is illustrated by the smaller amount of so-called heavy grade barley and the lower kernel weight of the barley from the diseased plots.

CONCLUSIONS AND DISCUSSION

The results of these experiments show that speckled leaf blotch of barley is capable of causing important losses in experimental plots. In commercially produced barley, losses may be even greater because damage to the straw could result in losses not encountered in hand-harvested plots and because there is greater chance of excessive "clean-out" of shrunken kernels. Disease development in the artificially inoculated plots usually was good but the infections were no more severe than those observed in commercial fields over the past 10 years.

Speckled leaf blotch usually develops rather slowly in the field at Winnipeg. Observations in 1952, 1954, and 1956 indicated an incubation period in the field of from 19 to 22 days. In 1955 and 1959, disease ratings were made 23 or 24 days after inoculation when the disease had killed many of the leaves. The long incubation period and the early maturity of barley permit a single generation of the pathogen after artificial inoculation and necessitate thorough application of the inoculum. The long incubation period indicates also that the fungus can exist and grow in plants for relatively

long periods without causing disease symptoms, which may account for the late and sometimes rather sudden appearance of the disease in farm fields.

Speckled leaf blotch has an adverse effect on the suitability of barley for malting purposes. The first result of kernel shrinkage is a higher proportion of loss through cleaning screens together with higher cleaning costs than would be the case with normal barley shipments. The object of malting is to convert the insoluble starch and protein material of the barley endosperm into water-soluble substances that can be extracted for subsequent industrial processing. While the ability of barley to affect this conversion does not appear to be impaired by the disease, the proportion of raw material available is less in the smaller kernels. The second result, therefore, is a reduction in the yield of malt extract. Both these results represent an appreciable economic loss and render the barley unacceptable to the malting industry.

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NOTE ON THE EFFECT OF SOME AMINO ACIDS ON MANGANESE TOXICITY IN POTATO[1]

In the course of work on the nutrition of *Phytophthora infestans* (Mont.) de Bary, it was noted that the methionine analogue dl-ethionine, when applied to potato in liquid culture, often caused a stem streaking similar to that resulting from manganese toxicity (3). Also, it was found that dl-methionine, when added to the solution, somewhat lessened the effects of excess manganese. In cauliflower it has been reported that changes in the manganese supply result in changes in amino acid content (1). Our observations suggested that an amino acid-manganese interaction might be demonstrable in the potato and several experiments were carried out to investigate this possible relationship.

Irish Cobbler potato was used in all tests. Plants were grown in washed sand to about 4 inches in height and then, with seed pieces detached, transferred to Hoagland's nutrient solution. Polyethylene containers holding 6.0 litres, each with seven plants supported in waxed plaster covers, constituted the growth units. Solutions were adjusted to pH 4.5, continuously aerated, and completely replaced every 2 weeks. Iron was supplied weekly as a 0.05 per cent solution of iron citrate. Manganese was supplied at 10 p.p.m. to achieve toxic effects and the amino acids added at concentrations of 20 to 100 p.p.m. All treatments were replicated and the plants grown for a period of 28 days. Manganese content of plant tissue was determined colorimetrically by the permanganate method (4).

Of 10 amino acids tested, it was found that dl-methionine, l-cysteine, l-arginine, l-tyrosine, l-cystine and l-lysine markedly reduced the severity of manganese streak, whereas l-aspartic acid, l-glutamic acid, l-alanine and l-valine had little or no effect. All but l-lysine and l-cystine produced severe stunting or root discoloration. l-cystine was studied further in several tests and invariably found to be effective in reducing both the stem streaking and foliar chlorosis caused by excess manganese. Tissue analysis (Table 1) showed that there was no appreciable difference in manganese uptake where l-cystine was supplied even though toxicity was much reduced.

[1]Joint contribution (No. 104) Experimental Farm, Charlottetown, P.E.I., and (No. 57) Research Station, Fredericton, N.B., Canada Department of Agriculture.

TABLE 1.—EFFECT OF 1-CYSTINE ON THE UPTAKE AND TOXICITY OF MANGANESE IN IRISH COBBLER POTATO

Treatment applied	Percentage of plants showing streak[1]	Manganese in dried tissue (p.p.m.)
10 p.p.m. manganese	24	1224
10 p.p.m. manganese+ 100 p.p.m. 1-cystine	2	1176
100 p.p.m. 1-cystine	0	110
Control	0	90

[1]Based on 42 plants per treatment

It is evident from these results that l-cystine does not prevent the uptake of manganese by the plant but, rather, that the effect is to counterbalance the toxicity of excess manganese in the tissue. It is possible that this may occur by rendering iron more available, in accord with the view that iron and manganese are antagonistic (2); or it may be that a direct imbibition occurs which may correct an amino acid imbalance in the plant.

ACKNOWLEDGEMENT

The authors acknowledge the technical assistance of J. N. Richard in carrying out this work.

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March 6, 1961

NOTE ON SELECTING SWEET CORN FOR EATING QUALITY IN EARLY GENERATIONS OF INBREEDING

Most sweet corn hybrids now in commercial production are inferior in flavour to some of the old open-pollinated varieties, e.g., Golden Bantam and Dorinny. Modern hybrids are superior in uniformity, productivity and appearance – characteristics which are essential for modern methods of production and marketing. Unfortunately, the consumer has been ignored in most of the recent breeding for market-type sweet corn.

Most sweet corn breeders select, during the inbreeding process, primarily on the basis of vigour, appearance, and productivity. It is not until the F_4 or F_5 generation that any attention is paid to eating quality. This is understandable, because the plant breeder does not want to sacrifice the most promising ears for taste tests. Ears from poorer plants may not be characteristic of those selected for propagation. By the time the lines have become fairly well stabilized, the chances of getting outstanding quality are very slight. Very little progress was made at Vineland, Ontario, in selecting for high eating quality using the standard procedure outlined above.

Eating quality of cooked corn-on-the-cob can be sub-classified as to tenderness, texture, sweetness, and aroma. In a breeding program it would be too time-consuming to evaluate each of these characteristics separately, even if instruments were available for the tests. Working with commercial hybrids, a close correlation was obtained between the author's rating of the taste of the raw corn and that of six consumers who rated them when cooked on-the-cob. Subsequently, evaluation of eating quality has been done in the field by tasting the raw corn.

The standard procedure was modified to give eating quality at least as important a place as appearance and productivity. Beginning with the F_2 generation, any plants which do not meet the standards for such characteristics as vigour, colour, ear height, and pest resistance are eliminated as their defects are noticed. In practice this seldom results in a border effect because a large proportion of the plants in a line is normally removed within a period of 2 or 3 days. All plants that survive this preliminary selection procedure are self-pollinated when the oldest silks are exposed about 2 inches, i.e., 2 or 3 days after they first appear. The pollination date is written on the ear bag. All kernels on an ear will be fertilized and begin development within a few hours of each other. All ears pollinated on a given date will approach optimum eating maturity on the same day. (At Vineland, depending on the weather, this is approximately 19 days later). At this time, the bag is removed and the husks pulled down from one side of the ear. If the ear is acceptable for colour of internal silks, row number and regularity, a bite is taken from the ear while it is still on the plant and a quality rating obtained. If the quality is good enough, the rating is written on the ear bag, the husks are pulled up around the ear and the bag replaced to stay on the plant until maturity. Any plant that is too low in any category is cut off at ground level. Hence, at harvest time,

only a few plants are left. Ears from these plants are dried and a final decision as to their retention is made during the winter.

The technique has several minor disadvantages. The kernels decay where the bite was taken but, even under the relatively humid conditions at Vineland, the mould usually does not extend to the uninjured kernels. The damage is no greater than that caused by a corn-borer or ear-worm. The inbreds developed by this method are so tender and high in sugar that greater care than usual must be taken to select for resistance to ear rots and for the ability to germinate quickly in cold soils. Perhaps the greatest disadvantage of the technique is the undignified posture that the corn breeder must assume during the sampling procedure.

This selection technique was begun in 1952. F_1 hybrids, using inbreds developed by it, have now been under test for 3 years and are outstanding for eating quality.

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February 14, 1961

NOTE ON PALLISER BARLEY

Palliser barley was developed by the Dryland Area Project Group of the Canada Department of Agriculture from a cross made at Lethbridge, Alberta. Its main attributes include superiority to Compana in yield, height, lodging resistance, and resistance to post-maturity stem break.

ORIGIN

Palliser originated from the cross Vantage x Compana made in 1951. The objective was to produce a two-rowed variety with longer, stronger straw than Compana. The F_1 and F_3 generations were grown in bulk in California and the F_2 and F_4 at Lethbridge. Selection for plant and seed type was carried out in the F_2 and F_4, and the F_5 was grown in progeny rows at Lethbridge in 1954. Barley infected with loose smut was sown in border rows on the windward side of the F_4 and F_5 material. Infection from this source was low, but very susceptible lines were infected by this natural inoculum and were eliminated. F_5 lines were selected primarily for straw characteristics, resistance to shattering, seed type, and pearling quality. Uniform lines were bulked individually and tested in a preliminary yield test in 1955. Palliser was among this group and was included in a regional test at Swift Current, Scott, and Lethbridge in 1956. In 1957 it was advanced to the Co-operative Two-Rowed Barley Test for a 3-year period. On the basis of its performance in these tests and in supplementary tests in Alberta and Saskatchewan in 1958 and 1959 it was licensed on April 19, 1960.

DESCRIPTION

Spike – Two-rowed; mid-long to long; emerged 0 to 2 inches; nodding; lax; lemma awn long, smooth or semi-smooth (awn barbing varies from approximately ¼ to ¾ of the length of the awn); glume awn equal to length of glume; glume hairs long, numerous; rachis edges with numerous long hairs.

Grain – Kernels large, uniform; hull smooth to wrinkled; aleurone yellow; rachilla short to mid-long with long hairs; lateral veins free from barbs and reasonably well defined; basal marking an incomplete horseshoe tending to crease.

Yield – Approximately 7 per cent higher than Compana and 3 per cent higher than Vantage in 49 tests on the Brown and Dark Brown Soils of Alberta and Saskatchewan in 1958 and 1959.

Maturity – Approximately 5 days later than Compana and 1 day later than Vantage.

Height – Equal to Vantage; considerably taller than Compana.

Straw Strength – More resistant to lodging than Compana but not equal to Vantage; much more resistant to post-maturity stem break than Compana but not quite equal to Vantage.

Resistance to Shattering – Highly resistant; appears to be equal to Compana.

Disease Reaction — Moderately susceptible to the common diseases of barley; similar to Compana but somewhat more susceptible to *Helminthosporium sativum.*

Quality — Similar but somewhat superior to Compana in pearling quality; not equal to Hannchen in malting or pearling quality.

ADAPTATION

Palliser should be well adapted on the Brown and Dark Brown Soils of Alberta and Saskatchewan where Compana is now the predominant variety.

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July 19, 1960

NOTE ON A VOLUMETRIC METHOD FOR THE DETERMINATION OF NUMBERS OF APPLE APHID, *APHIS POMI* DeG., ON SAMPLES OF APPLE FOLIAGE[1]

Assessment of the relative efficiency of aphicides against the apple aphid, *Aphis pomi* DeG., involves the counting of very large numbers of aphids that frequently occur on the terminal new growth of apple twigs. In order to reduce the time and labour involved, a volumetric method has been devised.

The terminal 10 centimetres of the current year's growth is cut from each of a number of twigs until a 25-gram sample is collected. This weighing is done in the field with a spring balance. The samples are then placed in wide-mouth storage jars and removed to the laboratory. Fumes of 4-methyl-2-pentanone are applied to the sample by placing a few drops on a sponge rubber pad in each jar. These fumes cause the aphids to release their stylets from the foliage (1). Each jar is then filled with approximately 800 millilitres of 70 per cent alcohol and shaken violently for a few minutes. Nearly all the aphids settle in the bottom of the jar.

Next, the foliage is removed; the contents of the jar, agitated with a swirling motion, are dumped into an Imhoff sedimentation cone. The pieces of foliage are then shaken individually below the surface of the alcohol in the cone, in order to release any aphids that remain adhering loosely to the leaves. The aphids settle out rapidly in the cones (Figure 1). Experiment showed that these wide-mouth graduates are the only type suitable for the purpose. Attempts to pour the aphid suspension into narrow graduates, or through funnels, left a large proportion of the insects sticking to the sides of the glassware. The absolute accuracy of the reading increases as the volume decreases; relative accuracy remains about the same throughout.

The sediment stratified into layers in the graduate. Aphids that were living at the time of the sampling fall out first, the larger before the smaller. Then dead aphids and cast skins are laid down and, finally, miscellaneous plant debris. This has the advantage that the volume of aphids which were alive when the foliage was sampled can be read easily without interference from other material.

Examination of the remnant of aphids adhering to the discarded foliage showed that at least 96 per cent of the aphids were removed by the procedure, provided the jars were shaken violently enough and that exposure to the fumes of 4-methyl-2-pentanone was adequate.

In order to convert volumes to numbers an estimate of the numbers of aphids in a known volume was made. All the instars in twelve 1-millilitre samples were counted. The numbers varied, dependent on the numbers of different instars that happened to occur in each sample. The mean number per millilitre was 2,070. The 95 per cent confidence limits were from 1,896 to 2,244. In round figures, for rapid conversion, it may be said, therefore, that there are 2,000 aphids per millilitre of sediment.

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[1]Contribution No. 57, Research Station, Research Branch, Canada Department of Agriculture, Summerland, B.C.

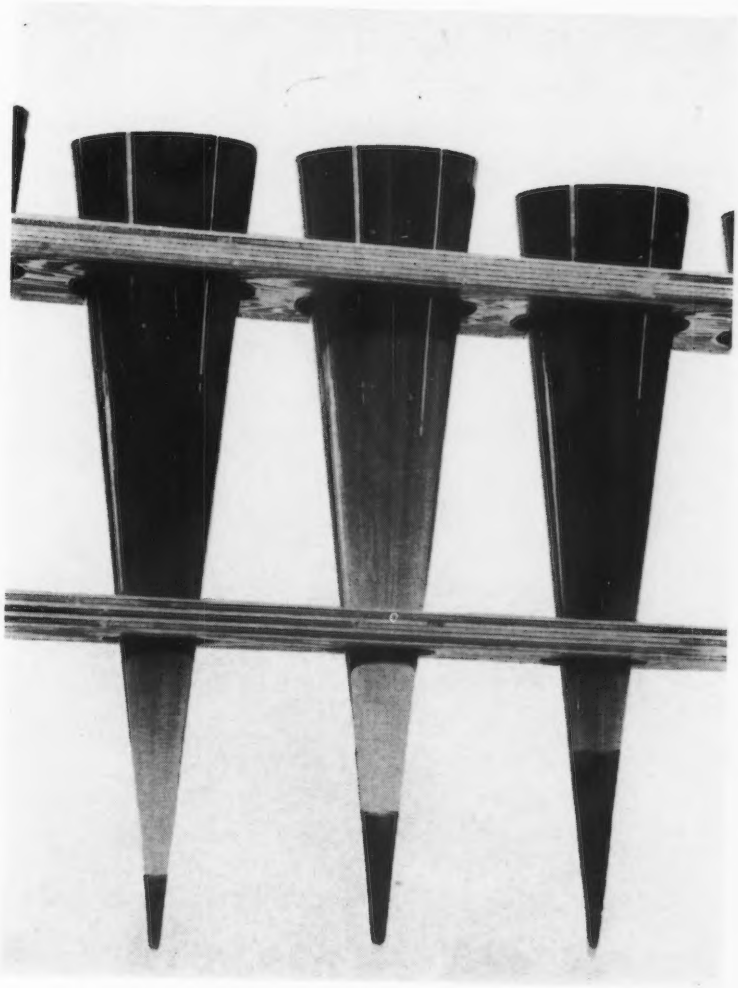

FIGURE 1. Sediments of aphids settling out in Imhoff cones.

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December 19, 1960

NOTE ON A MECHANICAL SEED DISPENSER FOR ROD-ROW PLOTS

The machine described in this note combines speed and accuracy of operation with simplicity of adjustment for seed of any size. Since it is constructed entirely of metal it is not subject to breakage and should last almost indefinitely.

The dispenser consists of a metal tube, which in its upright position is directly beneath a funnel which serves as supply hopper. In this position the seed drops from the funnel to fill all the available space in the tube. The tube is then tipped to a position in which the contents spill into a

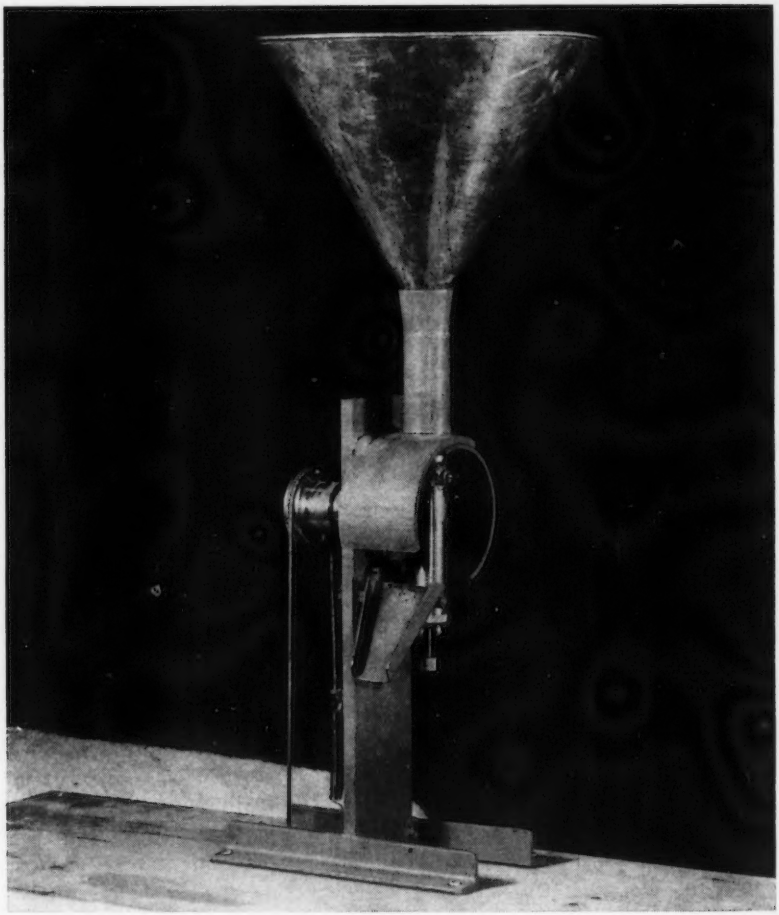

FIGURE 1.

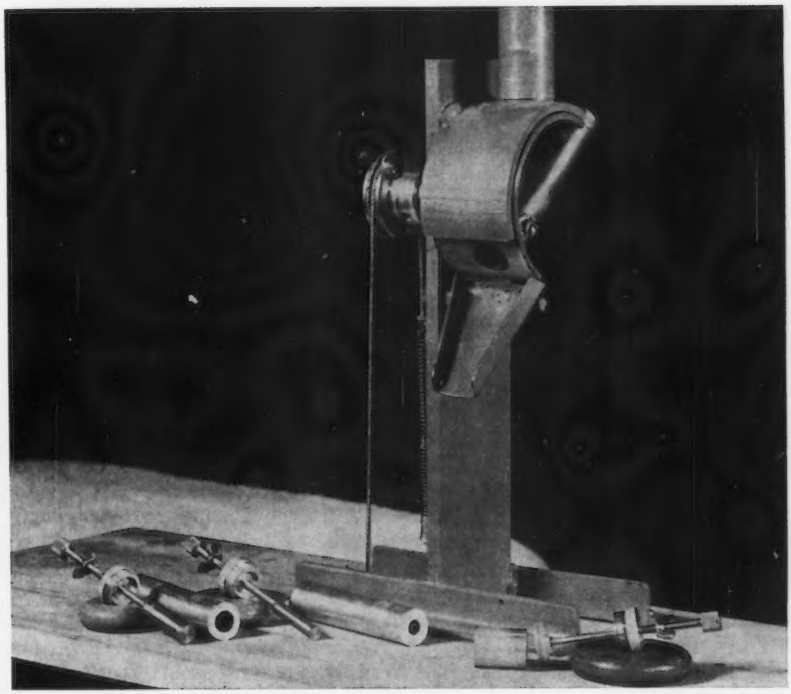

FIGURE 2.

chute and are directed into an envelope. Spring action then returns the tube to its upright position in which it refills for the next cycle. The dispenser is operated by a knee bracket under the table, leaving the operator's hands free. Adjustment for different sized seeds is provided by a piston mounted on a threaded shaft fitted in the lower end of the tube. For small grains, such as flax and rapeseed, auxiliary sleeves are fitted in the tube to reduce its inside diameter. Each of these auxiliary sleeves has its own piston and threaded shaft to provide fine adjustment for different varieties. The adjusting screw is located at the lower end of the tube so that adjustments can be made without emptying the supply hopper.

Figure 1 shows the dispenser in filling position. Figure 2 shows it in dumping position, but with the adjustment piston removed. This figure also shows the various pistons and auxiliary sleeves. The piston and sleeve at left are used for flax; those at centre are used for rapeseed. The piston at right is used without auxiliary sleeve for wheat, oats or barley. The auxiliary sleeves are held in position by a set-screw at the upper end of the tube. The tube for wheat, oats and barley has an inside diameter of ⅞ inch and is 5 inches long. The sleeve for flax has an inside diameter of ½ inch and that for rapeseed has an inside diameter of 5/16 inch.

The original model of this seed dispenser was constructed by students of Balfour Technical School in Regina, Saskatchewan, under the supervision of H. M. Bond, head of the Machine-shop Department at the school. Arrangements can be made with the school for construction of additional machines. The cost at time of writing is approximately $25.00 per unit.

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Regina, Saskatchewan

September 13, 1960

NOTE ON A METHOD OF PRODUCING AND STORING INOCULUM OF THE ALFALFA BLACK STEM FUNGUS, *ASCOCHYTA IMPERFECTA* PK.[1]

In 1955 a program of screening alfalfa for resistance to *Ascochyta imperfecta* Pk., the incitant of the black stem disease, was undertaken. In preliminary studies it was found that excellent infection could be obtained by spraying a heavy spore suspension of the pathogen, supplemented with 0.25 per cent gelatin, on 1-month-old seedlings and incubating them in a humidity chamber for a period of 5 days at 60 to 70°F. Spore suspensions were first obtained from cultures grown on potato sucrose agar, but as this proved unsatisfactory for producing large quantities of inoculum at frequent intervals, other methods of producing spores were investigated.

Whole grain media, as used previously (1), consisting of wheat, oats, or barley alone and in combination, were tested and it was found that the heaviest production of spores of *A. imperfecta* occurred on barley kernels. The medium was prepared by washing a 1-inch layer of kernels in a 1000-millilitre flask to remove light kernels and chaff, adding water to cover the kernels, and then autoclaving for 1 hour at 15 pounds pressure. The barley kernels were inoculated with 10 millilitres of a spore suspension and incubated at 70°F. for 3 weeks. Spore suspensions for inoculating alfalfa were made by agitating the kernels in successive quantities of tap water followed by straining through a sieve and fine cheesecloth. After sufficient spores were obtained, the barley kernels were either dried on paper towels over a source of warm air and stored in a refrigerator, or stored immediately after washing in a freezing compartment of a refrigerator. Subsequent suspensions were obtained from the same lots of kernels by washing the dried kernels, or thawing and washing the frozen kernels. Five spore suspensions over a period of 11 months were made from one lot of barley medium stored dry and six spore suspensions over a period of 2 years were made from a lot stored in a freezing compartment. Each spore suspension was streaked on an agar medium to check the purity of the inoculum. Despite the lack of precautions against contamination the resultant cultures were typical and only after several suspensions were obtained was there evidence of bacterial growth. No difference in virulence was observed between the initial and final suspensions obtained from any one lot of media.

To determine the ability of the fungus to produce spores on barley, each of two isolates of the fungus was transferred to four 250-millilitre flasks containing 50 cubic centimetres of sterile barley. After 3 weeks' growth, two of the flasks of each isolate were washed 10 times and two 20 times, with 100-millilitre aliquots of tap water. The last 100-millilitre aliquot in each case was kept separate, the others were bulked. Spore counts were taken with the aid of a haemycytometer on the last 100-millilitre aliquot and on the total quantity of spores obtained from each flask. Following the initial sampling, the barley cultures were frozen and at intervals during the next 6 months were removed, thawed, and sampled. The results are given in Table 1.

[1]Contribution No. 62 from the Canada Department of Agriculture Research Station, Winnipeg, Man.

TABLE 1.—SPORE CONCENTRATIONS IN SUSPENSIONS OBTAINED AT VARIOUS INTERVALS FROM CULTURES OF *A. IMPERFECTA* GROWN ON BARLEY AND FROZEN FOR STORAGE

Sampling interval	Number of spores x 10^{-6} per cc. of suspension[1]			
	20 washes (2000 ml.)	20th wash (100 ml.)	10 washes (1000 ml.)	10th wash (100 ml.)
3 weeks	23.6	5.3	52.0	10.8
10 weeks	10.7	6.4	9.8	5.1
16 weeks	15.5	3.2	10.3	4.1
26 weeks	6.3		5.8	

[1]Average of 4 flasks, 2 of each isolate

The data indicate the number of spores obtainable from a small amount of inoculum. There is also an indication that some growth occurred in storage before the cultures became frozen as most of the amalgamated suspensions had higher spore concentrations than the final aliquot of the previous sample.

This method of producing and storing inoculum has certain advantages: 1) large quantities of inoculum can be prepared with a minimum of media; 2) inoculum can be prepared in advance and shipped dry to other locations where it can be used at any time and as often as necessary; 3) no special equipment or techniques are required at the station where the inoculations are to be made.

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NOTE ON THE EFFECT OF RAIN, AND SPRINKLER IRRIGATION, ON THE PERSISTENCE OF SPRAY RESIDUES OF GUTHION AND SEVIN ON APPLE LEAVES[1]

During investigations to determine the persistence of residues of Guthion [*O,O*-dimethyl-*S*-(4-oxo-benzotriazine-3-methyl) phosphorodithioate] on apple foliage it was noted that the rate of decline increased sharply between the fourth and seventh day after spray application. The rapid decline occurred in an orchard of dwarf apple trees that had been irrigated by overhead sprinklers on the fifth day after insecticide application. With overhead sprinklers the upper surfaces of the leaves were continually drenched with water for a period of 8 hours. An examination was then made of data that had been obtained by this laboratory on residue decline under conditions of low sprinkler irrigation where the water stream never rose sufficiently high above the ground to wet the foliage. This information on overhead and low sprinkler irrigation is summarized as part of Figure 1 (two upper curves of upper graph; upper curve of lower graph).

In order to determine more precisely the effect of sprinkler irrigation on the weathering of spray residues, two pesticides, Guthion, 25 per cent wettable powder, and Sevin [1-naphthyl-*N*-methylcarbamate], 50 per cent wettable powder, were applied to dwarf Golden Delicious apple trees by means of a hydraulic hand-gun sprayer. The insecticides were applied at the rate of one-half pound active ingredient per 100 gallons of water to triplicate plots, each plot consisting of three trees.

At 0, 1, 3, 7 and 14 days after the sprays were applied duplicate samples, consisting of 25 leaves per sample, were picked at random from each plot. On each occasion the residue on the leaves of one sample from each plot was removed by extracting with an appropriate solvent (4). The leaves of the other sample were suspended by their petioles in a stand at a fixed distance from a revolving orchard sprinkler. Each surface of the leaves was sprinkled for 1½ hours. The amount of water that fell on each side of the leaves approximated 1 inch of rain. After the leaves were dry the residue remaining was extracted with solvent (4). Aliquots of the extracting solutions from all the samples were then analysed for Guthion and Sevin by colorimetric procedures (2, 3).

On all sampling days only trace amounts of Guthion and Sevin remained after controlled sprinkling and, therefore, these data cannot be shown in Figure 1. Residue curves for the non-sprinkled samples are shown in Figure 1 (lower curve of each graph).

The residue curves in Figure 1 show that overhead sprinkling, and rain, removed some of the Guthion residue; and rain removed some of the Sevin residue. The rain which fell on the second day after spraying was quite heavy, 0.13 inches in less than 1 hour. The loss appears to be fairly large, particularly in view of the fact that in the absence of wind only the upper surfaces of exposed leaves are subjected to weathering by rain or

[1]Contribution No. 63, Research Station, Research Branch, Canada Department of Agriculture, Summerland, B.C.

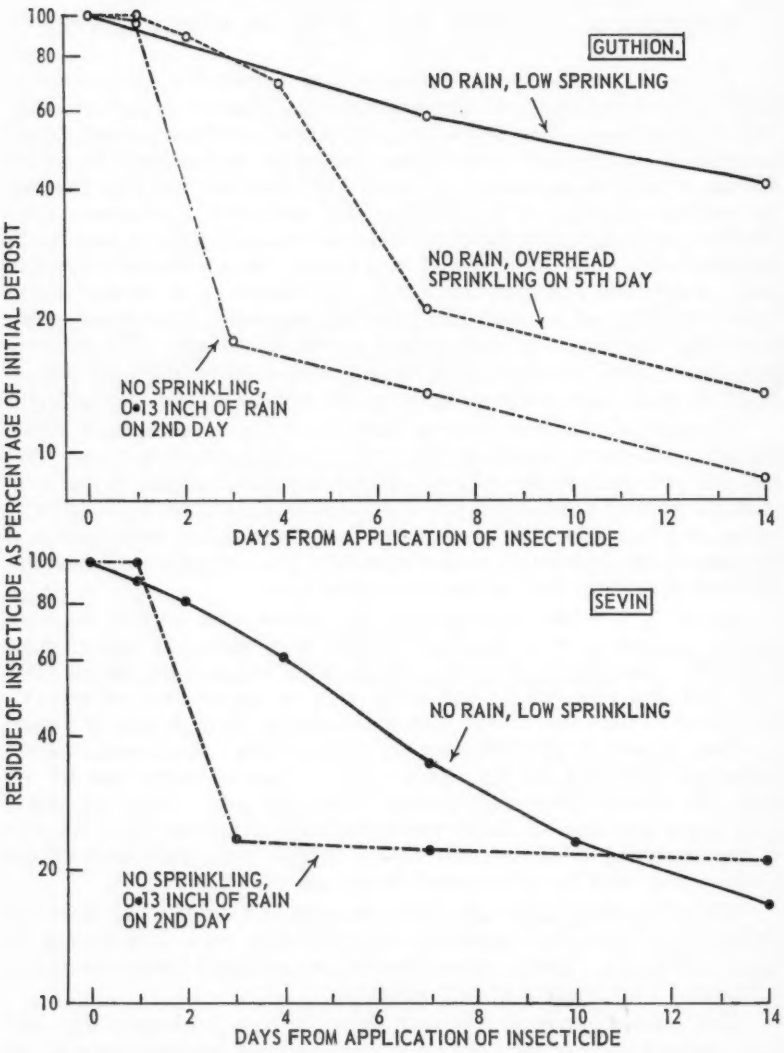

FIGURE 1. Persistence of Guthion and Sevin on apple foliage exposed to rain, overhead or low sprinkler irrigation, Summerland, B.C.

overhead sprinkling. Hightower (1) found that simulated rain on cotton plants reduced the residual toxicity of Guthion but not of Sevin. It may be that it is easier to wash off residues of Sevin on apple foliage than on cotton, or that the velocity and the size of the water droplets are important in the weathering of spray residues.

The results emphasize the importance of keeping accurate weather records when the residual toxicities of pesticides are being evaluated. They also indicate that, when overhead sprinklers are used, irrigation should be delayed as long as possible after spraying.

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NOTE ON A PORTABLE SHEAF DRIER

The storage or threshing of cereal sheaves harvested from experimental plots is often delayed because of dampness from rain or immature straw. A portable drier developed at the Research Station, Lethbridge, Alberta, has provided satisfactory drying of sheaves from cereal breeding plots and has been used extensively.

The construction and principal parts of the drier are illustrated in Figure 1. It consists of a 24-inch electric fan (Sirocco 2-G-20) powered by a ¼ h.p. motor with a capacity of 4300 cubic feet per minute at 1140 r.p.m., fan motor control with 6-ampere heater, four (or six for greater heating capacity) 500-watt strip heaters, a switch box, a magnetic starter, and a thermostat. The fan and strip-heaters are mounted on a 'Dexion' frame as illustrated and are enclosed on the sides, top, and bottom with asbestos board to control and direct the air flow. The temperature of the air flow is regulated by the thermostat, which is attached by a long cord to the magnetic starter and strip heaters and is usually placed in the material being dried. The entire drier is mounted on castors and is portable.

The drier is used in several ways. For rapid drying the sheaves are spread out on a wire mesh rack in a 9- x 9-foot room as illustrated in Figure 2. The rack should be completely covered with sheaves to prevent escape of air. The heated air is forced through a false door (Figure 2) under and up through the sheaves. The room contains an exhaust fan above the level of the sheaves but it is seldom used. A vent or window is sufficient to allow escape of the moist air.

Effective drying is also accomplished by simply directing the flow of heated air through a loose inverted V-stook of sheaves in the storage loft.

ACKNOWLEDGEMENTS

Acknowledgement is made to Norman W. Hall, technician, and H. F. Bell, electrician, Research Station, Lethbridge, Alta., for assistance in construction of this drier.

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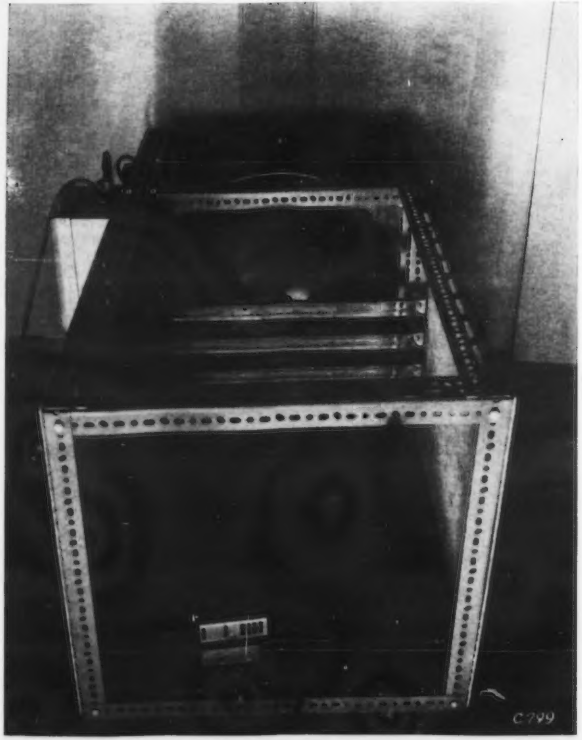

FIGURE 1. View of drier illustrating details of construction.

FIGURE 2. View of drier illustrating operation.

NOTE ON THE OCCURRENCE OF TWO PARASITES OF THE SIX-SPOTTED LEAFHOPPER, *MACROSTELES FASCIFRONS* (STÅL), IN MANITOBA[1]

A dipterous parasite, determined as *Tomasvaryella sylvatica* (Meig.) Pipunculidae, by J. G. Chillcott, Entomology Research Institute, Ottawa, Ontario, was reared from six-spotted leafhoppers collected in Manitoba in 1958. This is the first known occurrence of *T. sylvatica* parasitizing the six-spotted leafhopper. George[2] reared this parasite in August, 1959, from six-spotted leafhoppers collected near St. Catharines, Ontario.

A species of dryinid, identified by W. R. M. Mason, Entomology Research Institute, Ottawa, as *Pachygonatopus minimus* Fenton, was reared from the six-spotted leafhopper in 1958. A dryinid parasite, presumably the same species, was taken from six-spotted leafhoppers collected at Teulon, Manitoba, in 1954.

Parasitism of the six-spotted leafhopper by *P. minimus* has ranged up to 37 per cent and by *T. sylvatica* up to 25 per cent. *P. minimus* is also a predator of six-spotted leafhopper nymphs and adults.

Both species of parasites are being studied by the senior author and will be the subject of a later paper.

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[1]Contribution No. 81, Canada Agriculture Research Station, Winnipeg, Man.
[2]*Personal communication.* George, J. A., Plant Pathology Laboratory, Canada Department of Agriculture Research Station, St. Catharines, Ont.

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NOTE ON A VACUUM METHOD FOR PREPARING SLICED CUCUMBER PICKLES[1]

The development of a controlled pasteurization process for fresh cucumber pickles was reported by Etchells in 1938 (1). Since that time, pasteurization has become an important commercial pickling method. Sliced cucumbers often undergo varying degrees of plasmolysis during pasteurization in concentrated pickling syrups. In an effort to control this problem, a vacuum treatment of fresh cucumber slices was investigated. A promising method has resulted. It consists of removing the gases from fresh slices by subjecting them to a high vacuum and impregnating the slices with water or dilute syrup when the vacuum is released. The slices can then be manufactured into pickles by the normal fresh-pack method.

Successful experimental packs were prepared using cucumber slices one-half inch thick. The slices were placed in an enclosed vessel and treated for 2 minutes at a vacuum equivalent to 27 inches of mercury. The vacuum was released with water. Control samples were prepared by blanching slices in water at 160°F. for 5 minutes. The two lots of slices were then packed into jars containing a concentrated sugar-vinegar pickling solution and pasteurized by a recommended procedure (2). The pickles were examined after 3 months' storage for soluble solids and acid content, and for product yield, colour and condition.

The pickle liquor averaged 32.9 per cent soluble solids as sucrose and 1.46 per cent acid as acetic. Both treatments were essentially the same in this respect. The recovered yield and appearance of the product were as follows:

Pre-packing treatment	Product yield %	Colour	Condition
Vacuum (2 minutes at 27 inches —released with water)	103.8	Homogeneous	Slices firm with straight-cut edges
Control (hot water—160°F. for 5 minutes)	85.1	White centres	Slices severely plasmolyzed

The vacuum-treated slices withstood pasteurization in concentrated pickling syrup without evidence of plasmolysis and with a slight gain in product weight. The weight increase was attributed to the increased sugar in the slices. The colour of the vacuumized slices was excellent and showed a desirable homogeneity and translucence which was not evident in the control. Longer vacuum treatments were tried but gave substantially the same results. The control sample, which had received a short hot water blanch, showed severe plasmolysis and a considerable product yield loss. In preliminary tests, using slices which had not been blanched, the degree of product distortion and yield reduction was even more severe.

[1]Contribution No. 15 from the Experimental Farm, Research Branch, Canada Department of Agriculture, Morden, Man.

The vacuum can be released with dilute sugar syrup instead of water. However, the use of syrups more concentrated than 20 per cent sugar resulted in a loss of turgidity and a less effective impregnation of the cell tissue. The initial increase in the sugar content of the slices was only about 2 per cent when a 20 per cent sugar syrup was used to release the vacuum.

The principal advantages of the vacuum method are:

(a) Vacuum treated slices are firm and translucent.

(b) Thick cucumber slices, such as those found in sweet mixed pickles, can be packed directly from raw cucumbers without plasmolyzing, rather than from fermented stock.

(c) Possible improvement in the quality and product yield of fresh-pack sliced cucumber pickles.

ACKNOWLEDGEMENT

The initial advice of C. C. Strachan, who encouraged this investigation, is gratefully acknowledged.

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June 2, 1960